Project title:	**Lilies: Nutrition of glasshouse bulbs in peat-free and recycled peat substrates**	
HDC Project number:	PC/BOF 140	
Project leaders:	Gordon R Hanks Crop Biotechnology and Agronomy Team Horticulture Research International (HRI) Kirton Boston Lincs PE20 1NN	Susie Holmes ADAS Horticulture ADAS Boxworth Boxworth Cambridgeshire CB3 8NN
Report:	Final Report, July 2003	
Previous reports:	Annual Report, March 2001	
Key workers:	Gordon R Hanks – Joint project leader responsible for experimental programme (HRI) Susie Holmes – Joint project leader responsible for substrate and substrate analysis issues (ADAS Horticulture) Clive R Rahn – Soil scientist (HRI) Pippa Hughes – Research Assistant responsible for day to day running of project (HRI)	
Location:	HRI Kirton	
Project co-ordinators:	Dr Gordon J Flint Winchester Growers Ltd Herdgate Lane Pinchbeck Spalding Lincs PE11 3UP	Bob Goemans Parigo Horticulture Spalding Common Spalding Lincs PE11 3JZ
Date commenced:	1 April 2000	
Date completion due:	31 July 2003	
Keywords:	Lily, *Lilium*, bulb forcing, peat, wood-fibre, composted green waste, green compost, bark, coir, substrates, nutrition	

CONTENTS

GROWER SUMMARY 1

SCIENCE SECTION 10

Introduction 10

Literature review: substrates and fertilisers for lilies 15

Materials and methods 33

Results: crop performance 47

Results: analysis of substrates and foliage 71

Discussion 92

Acknowledgements 96

References 96

Appendix A: Crop results 103

Appendix B: Substrate and foliage analysis 121

Grower Summary

Headlines

- **Successful glasshouse lily production in a range of substrates**
  Trials have shown that high-quality lilies (cut-flowers and pot-plants) may be produced successfully in non-peat composts, such as mixtures based on wood-, bark- and green compost-derived materials. In some cases the flowers were judged superior to lilies raised in conventional peat substrates.

- **Reduce glasshouse lily production costs by recycling substrates**
  Trials showed that substrates based on peat, wood, bark and green compost can be re-used without compromising the quality of lilies grown for cut-flowers.

Background and expected deliverables

Glasshouse lilies are increasingly grown in trays or crates, rather than directly in the glasshouse soil. This method allows a more flexible use of glasshouse space, and avoids problems due to soil-borne pathogens or inappropriate soil pH levels. In the UK, as well as in Holland, 'box-grown' lilies are usually planted in peat, but the use of peat has become increasingly unacceptable because of environmental considerations. But there is little systematic knowledge of lily growing and nutritional requirements in alternative substrates, whereas growers have had many years' experience of growing in peat.

In this HDC-funded project, lily varieties from each of the main cultivar groups were grown in peat, in recycled peat, and in some commercial alternative substrates based on wood, bark, green compost and coir. The nutritional requirements of lilies in this range of substrates were investigated by varying base fertiliser levels and liquid feeding. Other aspects investigated included the suitability of these alternative materials for recycling, and for the production of pot-grown dwarf lilies. The outcome of the project is a definite set of recommendations for growing lilies successfully in peat-alternatives.

Summary of the project results

Evaluation of base nutrient levels for cut flower lily production in proprietary peat-free mixes

The production of box-grown glasshouse cut-lilies was investigated using the following substrates:

1. Peat
2. Peat and used peat (1:1 v/v)
3. Used peat
4. Wood- and bark-based mix (Melcourt Industries 'Sylvafibre' and 'Growbark', 7:3 v/v)
5. Wood-, bark- and green compost-based mix ('Sinclair Peat Free', William Sinclair Horticulture Ltd.))
6. Green compost- and coir-based mix (Eco Composts 'Eco Peat-free Professional').

Before use, each substrate was analysed and straight fertilisers added where needed to make the major nutrient content (N, P, K and Mg) about equivalent to peat to which 0.5, 1.0 or 1.5 kg/m^3 of a standard compound fertiliser (PG-Mix, 14:16:18 N:P:K) had been added (low, medium and high nutrient regimes). Where necessary, lime was added to raise the pH to 6.5. In this experiment no liquid feeding was applied. The lily cultivars grown were Brunello and Élite (Asiatic group), Royal Fantasy (L/A hybrid), Snow Queen (Longiflorum or Easter lily group) and Star Gazer (Oriental group).

These fertiliser amendments produced a useful range of concentrations of the major nutrients, and the results of substrate and foliage analyses are detailed in the science section of the report. By the end of cropping, the pH of the new peat and wood/bark substrates was about 6.5, because of the hard irrigation water, while the pH values of the wood/bark/green compost and green compost/coir substrates were higher at 7.0 to 7.5, although there were no signs of iron (Fe) or manganese (Mn) deficiency. At this point, N was depleted in the low nutrient regime, while in the wood/bark and wood/bark/green compost substrates N was depleted even in the high nutrient regime, probably due to greater leaching and immobilisation of N as the wood and bark continued to break down; despite this, foliar concentrations of N were all satisfactory. The K levels of leaves were higher in the green compost/coir substrate, and, possibly as a consequence, the levels of magnesium (Mg) in the foliage were somewhat low. In spite of the high pH, leaf manganese (Mn) levels were higher, but well below harmful levels, in the wood/bark/green compost substrate.

Stems were longest and heaviest in the wood/bark and wood/bark/green compost substrates, and shortest and lightest in the green compost/coir substrate. The higher nutrient regimes produced plants with shorter stems. There were extensive lengths of basal stem with yellowing leaves (basal zone) in cv Brunello, and short lengths of basal zone in cv Snow Queen. The length of the basal zone decreased with increasing fertiliser levels, and was longest in the green compost/coir substrate and shortest in new peat. In cv Snow Queen only, foliage colour was markedly affected by treatment, with pale leaves under the low nutrient regime, and especially so in the non-peat substrates. The largest numbers of viable (successfully opening) florets developed using the wood/bark and wood/bark/green compost substrates, and the least with the green compost/coir substrate. There was no significant effect of nutrient regime on floret numbers. Root development, judged from visual assessments at the end of cropping, was good in the wood/bark substrate and poorer in the green compost/coir substrate; and it was better in new than in recycled peat. Using different substrates and nutrient regimes had a statistically significant, but commercially insignificant, effect on cropping dates. Flower vase-life showed no significant differences due to the treatments applied.

Brown marginal and leaf-tip scorch lesions, usually attributed to the effects of *Botrytis elliptica* or nutrient effects, respectively, were frequently found, although in the several samples examined in the laboratory, *Botrytis* was not isolated. There were many such lesions in cvs Brunello and Royal Fantasy, and few in Snow Queen and Star Gazer. Most lesions were found in plants in new peat, fewer in the new and used peat mixture, and some in the green compost/coir substrate. In new peat, higher nutrient regimes led to more lesions. There were few lesions with the wood/bark and wood/bark/green compost substrates. In a subsidiary experiment with Ėlite, a cultivar with a strong tendency for leaf scorch, bulbs were grown in the same six substrates but at the medium nutrient regime only. There were notable effects of substrates on the numbers of leaf lesions: leaf-tip scorch lesions were few in plants grown in wood/bark and wood/bark/green compost substrates, intermediate in used peat and green compost/coir substrates, and most numerous in new peat. Lesions characteristic of *B. elliptica* followed a similar trend, except that there were relatively more of these in the wood/bark/green compost substrate. The overall numbers of lesions in the two wood-based substrates were low.

This experiment showed that substrates based on wood/bark or wood/bark/green compost mixtures have a strong potential for use in growing lilies, equalling or surpassing the quality of plants grown in peat in this instance. The wood/bark mixture used produced the best root growth, the longest and heaviest stems, most florets per stem and least leaf lesions. The length of the basal zone of the stem was, however, shortest in peat-grown plants. In practical terms, cropping dates and the length of the cropping period, and vase-life were not affected by the treatments applied. From this trial it also appeared likely that other peat-free materials, based on green compost and coir, were likely to be of potential use when mixed at appropriate rates with wood- or bark-based materials. Compared with peat, the three alternative substrates held water less well and so needed more frequent watering.

Evaluation of base fertiliser and liquid feeding regimes for cut flower and pot lily production in proprietary peat free mixes

Exploiting the results from the previous year, lily growth was investigated in mixtures of green compost (Eco Composts 'Eco Base') and wood-based (Melcourt Industries 'Sylvafibre') substrates at ratios of 1:3 and 1:1. These were compared with production in the new peat and wood/bark ('Sylvafibre' plus 'Growbark') substrates used previously.

<u>Substrates tested:</u>

1. New peat
2. Green compost- and wood-based mix (Eco Composts 'Eco Base' and Melcourt Industries 'Sylvafibre'), 1:3 v/v
3. Green compost- and wood-based mix ('Eco Base' and 'Sylvafibre'), 1:1 v/v
4. Wood- and bark-based mix (Melcourt Industries 'Sylvafibre' and 'Growbark', 7:3 v/v)

Base fertiliser levels were adjusted as before, except that rates equivalent to 0.25, 0.75 and 1.25 kg/m^3 of PG-Mix were used, and all substrates were used both with and without a liquid feed (providing 180 ppm N, 60 ppm P_2O_5 and 180 ppm K_2O). In addition to growing cvs Brunello, Royal Fantasy, Snow Queen and Star Gazer in boxes for cut-flower production, the same treatments were used for producing pot-grown lilies of cv Butter Pixie (dwarf Asiatic) and of a new dwarf Longiflorum cultivar.

For cut-flowers, the wood/bark substrate produced the longest and heaviest stems, and the 1:1 mix of green compost/wood substrate the shortest and lightest. Stem length was slightly enhanced by using a liquid feed, and stem weight similarly by using a liquid feed and by increasing the rate of base fertiliser. Effects on stem length due to base fertiliser level were more complicated, however, probably because different cultivars had different optima for nutrient levels. In peat, for example, an increasing level of base fertiliser increased stem length in Brunello and reduced it in the other cultivars, but the opposite was true using the 1:1 green compost/wood substrate.

Several other aspects of plant quality were affected by the experimental factors. Only cv Brunello produced stems with a long basal zone, and this was much affected by treatments. The basal zone was short in peat-grown plants, irrespective of fertiliser regime, and in the alternative substrates, especially with liquid feed and the higher base fertiliser rates. There were long basal zones in Brunello plants grown in wood/bark and green compost/wood substrates used without liquid feeding. The greatest number of viable flowers per stem was obtained using the wood/bark substrate, and the lowest with 1:1 green compost/wood substrate. Increasing base fertiliser levels and using a liquid feed boosted floret numbers. Foliage colour was better in peat and wood/bark substrate (except in cv Star Gazer, which was unresponsive), and was also improved by increasing fertiliser levels and using a liquid feed. Cropping date and cropping period were not affected by the experimental treatments to any practical extent.

Brunello and Royal Fantasy had many leaf lesions when grown in peat, few when grown in wood/bark substrates, and virtually none in green compost/wood mixtures. Snow Queen had most lesions when grown in peat and wood/bark substrates, but also significant numbers in the green compost/wood substrates, and lesion numbers were reduced through applying a liquid feed or increasing the base fertiliser rate. In Star Gazer, leaf lesions occurred only when grown in wood/bark mix with the highest fertiliser regime.

In the pot-plant experiment, the dwarf Easter lily cultivar produced taller plants in peat and wood/bark substrates, and shorter plants in green compost/wood substrates, whereas cv Butter Pixie was tall in peat and shorter in all other substrates. Using a liquid feed produced longer leaves (wider plants) in both cultivars, and both produced the widest plants when grown in peat and the narrowest when grown in 1:1 green compost/wood substrate. In the Easter lily cultivar increasing the base fertiliser levels increased plant width, whereas cv Butter Pixie was unresponsive. Other characteristics of Butter Pixie were little changed by treatment: it was largely free of leaf lesions, had no significant basal zone, generally its foliage was of good colour, and no differences were recorded in its shelf-life. In the dwarf Easter cultivar there were more leaf lesions when grown in peat than other substrates, and more where a liquid feed was used. Liquid feeding also prevented the production of a basal zone and ensured good foliage colour. The shelf-life of the dwarf Easter lily was significantly longer grown in peat and in wood/bark substrate than in 1:1 green compost/wood substrate, and slightly shorter with a liquid feed.

These findings confirmed those about wood/bark-based substrates from Experiment 1. They demonstrated that a green compost compost-derived material could be used successfully in combination with wood/bark-based materials, but in this case the proportion of green compost substrate should be 25% or perhaps only 20% to allow a safety factor.

Evaluation of base fertiliser and liquid feeding regimes for cut flower lily production using recycled peat and peat-free substrates

In the last experiment in the series, substrate recycling was investigated. The four substrates as listed below were used either as the new materials, or were recovered from the previous year's crop for re-use. The used substrates were either used without further treatment or were first heat-sterilised. The fertiliser levels of all materials were adjusted to an equivalent of 0.75 kg/m^3 PG-Mix, and all substrates were liquid fed as before. Only cvs Brunello and Star Gazer were used in this experiment.

<u>Substrates:</u>

1. New peat
2. Used peat
3. Used & sterilised peat

4. New green compost- and wood-based mix (Eco Composts 'Eco Base' and Melcourt Industries 'Sylvafibre'), 1:3 v/v
5. Used green compost- and wood-based mix (Eco Composts 'Eco Base' and Melcourt Industries 'Sylvafibre'), 1:3 v/v
6. Used & sterilised new green compost- and wood-based mix (Eco Composts 'Eco Base' and Melcourt Industries 'Sylvafibre'), 1:3 v/v

7. New green compost- and wood-based mix ('Eco Base' and 'Sylvafibre'), 1:1 v/v
8. Used green compost- and wood-based mix ('Eco Base' and 'Sylvafibre'), 1:1 v/v
9. Used & sterilised green compost- and wood-based mix ('Eco Base' and 'Sylvafibre'), 1:1 v/v

10. New wood- and bark-based mix (Melcourt Industries 'Sylvafibre' and 'Growbark', 7:3 v/v)
11. Used wood- and bark-based mix (Melcourt Industries 'Sylvafibre' and 'Growbark', 7:3 v/v)
12. Used & sterilised wood- and bark-based mix (Melcourt Industries 'Sylvafibre' and 'Growbark', 7:3 v/v)

Stem lengths were similar in Brunello, irrespective of treatments. Stems of Star Gazer were shorter in peat and in the 1:3 green compost/wood substrate, than in other substrates. Brunello stems were relatively light in weight grown in peat. Growing in new 1:1 green compost/wood mix, both Brunello and Star Gazer gave lighter stems. There were fewer viable florets using the 1:1 green compost/wood mix. Foliage colour was pale in plants grown in new 1:1 green compost/wood substrate, especially in Brunello. Cropping date and cropping period were not affected by the experimental treatments to any practical extent. In Brunello most leaf lesions occurred in new peat and in new green compost/wood substrate, and least when these substrates were re-used. In Star Gazer, most lesions occurred in recycled wood/bark substrate. There were no significant effects of treatments on vase-life. No significant effects were observed due to sterilising or not sterilising the used substrates.

The experiment showed that all three types of substrates could be recycled successfully. In this case, sterilising used substrates did not add to plant quality. Any adverse effects due to using new 1:1 green compost/wood substrate were not present when the material was re-used, indicating that composting had continued to take place. It is important that substrates of this type are thoroughly composted, the more so where they made up a high proportion of substrate mixtures.

Literature review

The project included a literature review on substrates and fertilisers for lilies, disorders relating to nutritional factors, tissue levels of nutrients, potential substrates, other planting factors and the interactions of nutritional factors with pests and pathogens of the crop. Details are included in the science section of the report.

Overall conclusions

<u>Box-grown cut-flowers</u>

Five important lily cultivars – Brunello, Élite, Royal Fantasy, Snow Queen and Star Gazer were box-grown in peat and in proprietary substrates based on wood, bark, green waste and coir, referred to here for convenience as wood/bark, wood/bark/green compost, green compost/coir and green compost/wood substrates.

The main findings can be summed up as follows:

- *Cropping dates and length of cropping period*
  There were some significant effects of substrates and fertilisers on the date and period of flower cropping, but these were small and commercially insignificant – often less than 1 day.
- *Flower yield*
  Flower yield was unaffected by substrate and fertiliser treatments.
- *Stem length*
  The longest stems were consistently obtained using wood/bark and wood/bark/green compost substrates. Substrates based on green compost gave short plants, sometimes particularly affecting the extension of the inflorescence.

Peat substrates gave intermediate results. Base fertiliser added at the highest rate (equivalent to using 1.5 kg/m3 PG-Mix) sometimes resulted in shorter stems, and low rates tended to give longer stems. Using a liquid feed, combined with a low rate of base fertiliser, enhanced stem length.
Cultivars varied in the extent to which they responded to treatments by altered stem lengths: for example, Brunello was relatively unresponsive.

- *Stem weight*
  Wood/bark substrates also produced the heaviest and densest stems, while those from plants grown in green compost substrates were the lightest. Peat substrates generally produced stems of intermediate or low weight. Medium rates of base fertiliser, and using a liquid feed, also produced heavier stems.
- *Length of basal zone*
  The premature loss of basal leaves is a quality problem in some lily cultivars, and here it was notable in cultivars Brunello and Snow Queen, although it was much shorter in the latter. Growing in wood/bark, wood/bark/green compost and new peat substrates gave Brunello plants with short basal zones, while the basal zone was long using new (but not recycled) green compost substrates. Liquid feed treatments reduced the length of the basal zone. In Snow Queen, the basal zone was shortest in peat and where a high rate of base fertiliser was used.
- *Floret numbers*
  The highest numbers of viable florets (and conversely the lowest numbers of abscised or aborted florets) occurred in wood/bark substrate, and the lowest using substrates based on green compost (green/coir and 1:1 green/wood substrates). Increasing base fertiliser levels or using a liquid feed resulted in more viable florets.
- *Foliage colour*
  In this project Snow Queen was the cultivar most affected by pale foliage. Growing in peat, or in any substrate with a high rate of base fertiliser, produced Snow Queen plants with darker foliage, while using alternative substrates with a low rate of fertiliser produced pale foliage. As mentioned for the length of the basal zone, in the case of green compost substrate this disadvantage applied only to the new material, once recycled the results were satisfactory. Higher rates of base fertiliser, and using a liquid feed, gave darker foliage.
- *Leaf lesions*
  Lesions encountered include leaf scorch, *Botrytis*-like and other lesions. The numbers of leaf lesions varied with treatment in Brunello, Élite and Royal Fantasy, where they occurred mostly in plants grown in new peat with a high fertiliser rate, with many fewer lesions in wood/bark, wood/bark/green compost, 1:1 green/wood and recycled peat substrates. In the leaf scorch-prone cultivar Élite there were very few lesions in the wood/bark substrate, in comparison with other substrates. New substrates produced more lesions than recycled materials. Increasing base fertiliser levels or using liquid feed resulted in more lesions. There were also leaf lesions in Snow Queen, but their numbers did not vary with treatment. Leaf lesions were rare in Star Gazer.
- *Root growth*
  Root growth was more extensive in wood/bark and new peat substrates, than in the other substrates.
- *Vase-life*
  Vase-life was unaffected by substrate and fertiliser treatments.

Pot-plants

- Similar trials were carried out using two pot-grown dwarf lilies, cv Butter Pixie and a new longiflorum cultivar. These varieties were quite different in their characteristics.
- Butter Pixie was shorter in alternative substrates than in peat, an advantage for a pot-plant, and was unresponsive to fertiliser levels regarding plant height and width, and was not prone to leaf lesions, a basal zone or pale foliage.
- The dwarf longiflorum cultivar was shorter in green compost/wood substrate than in peat or wood/bark substrates. It was shorter and wider using high fertiliser rates, had more leaf lesions in peat than in alternative materials; a liquid feed reduced lesion numbers and basal zone length and improved foliage colour.
- Substrate and fertiliser treatments did not significantly affect the time in the glasshouse to reach marketing stage.
- In the dwarf longiflorum cultivar growing wood/bark substrates, the shelf-life was slightly longer than in some other materials, a useful finding as there are sometimes concerns in the industry about shelf-life in peat alternatives.

Financial benefits

Sales of cut-flowers continue to increase in the UK, a high percentage of these being imported. Lilies grown under protection are popular for their exotic blooms available in a wide range of colours and forms over a long period. Although these bulbs are imported, flower production takes place in the UK, and growers here need to be able to maintain quality and add value to maintain this production. At present, Defra statistics show that just over 20 million lily bulbs are grown under protection in the UK annually. Most of these are now being grown in peat, and sales will very likely be threatened by pressure from the 'peat lobby' if the industry does not move away from using it.

This project has demonstrated that high quality cut-flower and pot-grown lilies may be produced in various non-peat substrates, including wood, bark and green compost materials and mixtures. At the present time these alternative materials are slightly more expensive than peat. However, continuing to use 100% peat is probably "not an option" in growing lilies for the multiple retailer sector, whereas reducing the amount of peat used is a good compromise and a way of gradually reducing peat usage over several years. In the short-term, while there may be some additional costs to growers using alternative substrates, this should be balanced by maintaining production. To an extent, any higher costs will need to be balanced by a more realistically priced product, produced with greater 'added value' and better marketing. The recycling of used substrates is a significant way of reducing costs: not only can existing stocks of used peat be used in mixture with new substrate, but the present trial has shown the potential for recycling the alternative substrates themselves.

With the availability of improved genetic dwarf lily cultivars, it may be possible to increase pot-lily production and sales, without the necessity for using growth retardants. Earlier attempts using standard cultivars were often flawed by poor quality.

Action points for growers

- Cut-flower producers currently using peat as their substrate for glasshouse lilies should consider a managed change to reduced peat usage as necessary to meet their customers' requirements. They should budget for losing the convenience, familiarity and cheapness of peat, in return for maintaining sales. Peat substitution could be carried out in stages, initially concentrating on diluting new substrate with existing supplies of recovered peat. The recycled peat could be augmented initially by limited supplies of new peat, adding between 10% (as in some Dutch recommendations) and 50% (as used in this project) of new peat. In this case, supplies of peat from less sensitive sources might be investigated. As further information on using non-peat substrates is accumulated, alternative substrates might be added to recycled peat, and in turn the alternative materials could be recycled.

- Where a substantial supply of used peat (or other substrate) is available, growers might consider investing in sterilising equipment to extend the life of their supply of recycled peat.

- Particularly encouraging results have been obtained growing lilies in wood/bark-based substrates, and in mixtures of these with some green compost. As these alternative materials are heavier and less water-retentive than peat, some changes to handling and irrigation practices may need to be considered.

- Many materials may be unsuitable for use in raw state, and may need mixing with at least equal proportions of peat. Levels of peat addition around three times that of alternative substrate were found to be appropriate for use with green compost materials.

- Where a different material is being used for the first time, it should be analysed before use and fertilisers added according to need. In most cases, low to medium rates of fertiliser addition should be used (equivalent to 0.75 kg PG-Mix (14:16:18) /m^3). In the case of bark substrates, additional N may be needed. Easter (longiflorum) lilies are more nutritionally demanding than other types of lilies. Medium rates of base fertiliser should be used with substrates based on peat, and low rates with substrates based on green compost, wood or bark. It is recommended that liquid feeding should be routinely used.

- There is scope for increasing the production of pot-grown lilies using alternative substrates and the newer, improved dwarf cultivars that do not require use of a growth retardant.

<u>IMPORTANT NOTE ON GREEN COMPOST</u>

Growers must be confident of supplies of green compost and satisfy themselves and their customers, that there has been adequate quality control and quality assurance implemented at the site of source of the green compost. It is doubtful if green compost produced to PAS 100 standards is adequate for inclusion in growing media for horticultural crops. WRAP have sought to improve these standards, but it will be the growers' responsibility to satisfy himself/herself with the material that they use.

Science Section

INTRODUCTION

The glasshouse production of lilies is an important component of the flower-bulb and cut-flower sectors of UK horticulture. Over 20 million lily bulbs are grown under protection (glass or polythene) annually (Defra, 2003), with an annual farm-gate value of over £2m (J.B. Briggs, personal communication). Lily growing encompasses a wide range of attractive cultivars, and all-year-round production is possible. While in Europe most glasshouse lilies are grown for cut-flowers, pot-grown lilies are also increasing in importance (as they already have in the US).

It is estimated that, of lilies grown for commercial flower production in the UK, probably 50% of the Asiatic cultivars, and most of the Oriental and Longiflorum (Easter lily) cultivars, are now planted in boxes or trays of peat substrate[1], rather than in the glasshouse soil (G.J. Flint, personal communication). By planting in a 'sterile' substrate such as peat, the need to sterilise glasshouse soil (e.g., using methyl bromide or steam) or to incorporate a fungicide to control soil-borne diseases (such as *Phytophthora*, *Pythium* and *Rhizoctonia*) is avoided. Iron and manganese deficiency, a problem for lilies (especially Oriental cultivars) grown in soils with a high pH, is also avoided. Handling bulbs in containers facilitates the provision of temperature treatments and permits part of the growth cycle to be made in cold stores, improving rooting and maximising the use of glasshouse space. As long as due attention is paid to irrigation, nutrition and the development of a good root system, 'box growing' of lilies in peat is a successful and efficient technique.

Unlike forced bulbs such as tulip and narcissus, glasshouse lilies are a relatively long-term crop, generally considered nowadays to require sustained levels of nutrients to produce high quality flowers and foliage. Tried and tested recommendations are available in both UK and Dutch literature for the nutrition of lilies in peat substrates. However, there are environmental pressures towards using peat-free, or at least reduced-peat or recycled-peat, substrates. The use of recycled peat reduces demands on peat extraction and utilises an otherwise waste product. All growers will in the future have to satisfy their customers that they have a sound environmental policy covering the use of all resources wisely. The peat debate is likely to assume more prominence for forced and glasshouse bulbs, as well as for ornamental plants in general. Suppliers of multiple retailers, in particular, are likely to come under increasing pressure to use sustainable alternatives to peat wherever possible. Commenting on this debate is outside the scope of the present project, which is simply a pragmatic response to the current situation. At present little information is available on the management and nutrition of lilies in substrates other than peat.

The HDC funded a trial on the use of peat alternatives for bedding plants in 1995 (PC 113). This work highlighted the different irrigation and nutritional management required for alternative substrates. The conclusions were that some of the peat alternatives could produce acceptable plants, if they were managed appropriately in terms of irrigation and nutrition. The issue of the shelf-life of bedding plants in alternative substrates is crucial: this would also be important for pot-grown lilies, although less crucial for the cut-flower crop. Another HDC-

[1] Throughout this report the term 'substrate' is used to cover growing media and potting composts.

funded project, HNS 43, showed the potential of using substrates with low nutrient contents, such as wood-, bark- and coir-based materials, for nursery stock.

More recently, new alternative products have been developed, and have been tested with bedding, pot and nursery stock plants, but not with lilies. For example, composted green waste has been added to substrates used for other crops, and, in the right proportions, this might also be possible in growing lilies. On-nursery trials with bedding and nursery stock plants have shown the potential of wood- or bark-based, peat-free substrates, including the incorporation of up to 20% of composted green waste**.** There could be other benefits from using composted green waste, as it is known to have a suppressive action on soil fungi such as *Phytophthora* and *Pythium*.

A growing phenomenon in bulb- and other cut-flower production in the Netherlands is 'aquaculture'. Used on a large scale for tulips, aquaculture techniques are likely to be developed for many other flower crops, including lilies which, until recently, have been considered unsuitable for this type of culture because of the need for long-term support and for allowing stem rooting. However, it is considered that conventional (solid substrate) lily growing will continue to have a place for many years to come, and, indeed, the high degree of capitalisation involved may mean that aquaculture remains unsuitable for many horticultural enterprises.

The present project, carried out over three years (2000-2002), involved three stages:

- Comparison of growing lilies in peat, used peat and alternative (wood-, bark-, green compost- and coir-based) substrates.
- Development of nutritional recommendations for growing lilies (including pot-plants) in selected alternative substrates (including mixtures of wood-, bark- and green compost-based products).
- Testing alternative products for their suitability for re-use, with or without sterilisation.

A great variety of substrates, old and new, is available for trialling in horticulture. Those substrates chosen for the lily study included ones that are both considered 'environmentally friendly' and likely to continue to be available to growers in the near future at economic prices and as a consistent product. More information on the substrates chosen is given in the next section of this report. The nutrition of the crop was studied by using different levels of base dressing, and crop growth, flower production and quality, ease of management and substrate and plant nutrient levels were recorded.

<u>The choice of substrates for growing glasshouse lilies</u>

There is an ongoing debate over the sustainability of peat, particularly peat from lowland raised mires, as the basis of horticultural substrates (Bragg *et al.*, 2000). Reduction in peat consumption for growing lilies could be achieved either by re-cycling peat or using alternative materials. The materials used in this project have been used in trials with other horticultural crops, such as bedding plants and nursery stock, but not, to the authors' knowledge, for the growing of lily bulbs. Although there was some interest in peat alternatives in the Netherlands in the early 1990s, the quest of Dutch research at the time this project was begun was aimed at recycling peat, and, for tulip, iris and hyacinth (but not lilies), the development of hydroponics systems (J.B. Briggs, personal communication, based on a study tour to The Bulb Research Centre, Lisse, and elsewhere in the Netherlands, February

2000). In the Netherlands peat is reported to be recycled up to 16 times after steam-sterilisation, with 10% of new peat being added each time to make up the volume. Since that time new developments have taken place in the Netherlands in the 'hydroculture' of a wide range of cut-flowers, although it is unlikely that this technology will be applicable to all growers or in the short-term. With horticultural crops other than bulbs, in the limited instances where peat alternatives are being used in the Netherlands, there is an emphasis on coir (Smith, 1995), but in the UK the environmental lobby is not enthusiastic about this material. Coir is not an indigenous product and has to be transported over large distances. In the UK, timber/forestry by-products (Aaron, 1973; Selmar-Olsen *et al.*, 1983; Riddiough, 1999) and green composts (Rainbow *et al.*, 1998) are considered by some to be more 'sustainable' in the longer term as peat replacements for the horticultural industry.

The substrates chosen for use in this project are described below. Their analyses before being amended are summarised in Tables 1-5. Some estimates of the prices of these materials were included in the First Annual Report on this project, but these are very dependent on a number of factors including transport costs. It is suggested that individual quotations should be sought for specific requirements.

Peat

Peat is an excellent substrate because of its ability to hold good levels of both air and water, and its inherently low pH and nutrient status that allow control of plant nutrition. Although there are many types of peat, it is possible to obtain very consistent supplies from any one area, which gives growers confidence. Peat also has the advantage of being cheap, because it requires little processing - the main cost is that of transport. Peat has a low biological activity, which may be useful in some respects, but a more microbiologically active substrate with a greater ability to hold and release nutrients could have advantages in some situations (e.g., where there is less use of inorganic fertilisers and pesticides).

The peat used in this project was a typical medium-grade Irish sphagnum peat (Shamrock Horticulture). It had a low 'fines' content (<1mm particles) and a low pH (4.2) and nutrient status, as would be expected. Such peat would have a lower buffering capacity (the ability of a material to hold and then release nutrients) than a substrate with green compost or bark, and is less 'biologically active'; it is, however, a very consistent material and is competitively priced which has advantages for growers. There is also a reasonable amount of research information on the management of peat-based substrates for glasshouse lilies, which may give growers more confidence in using them compared with some of the alternative substrates.

Recycled peat

The recycled peat used in this project was supplied by Winchester Growers Ltd., Pinchbeck, Spalding, Lincolnshire. It was Irish sphagnum peat that had first been used for forcing tulips, for which a proportion of sand was added, and it had then been recycled for glasshouse lilies. It had not been sterilised. The pH and available nutrient content of this peat were higher than that of the fresh peat, because lime, fertiliser and sand had been added and it had been watered with hard water. The recycled peat would have become more humified and compacted in use, and therefore had a relatively high bulk density (585 g/litre), so it was less free-draining than the fresh peat. It contained some remains from previous crops, and would be less 'sterile' than fresh peat. It would have a higher buffering capacity than new peat. In this project recycled peat was used on its own and also in a 50:50 mix with new peat.

Melcourt Industries 'Sylvafibre' and 'Growbark' Mix (wood- and bark-based substrate)
Sylvafibre is the brand name of composted wood fibre produced by Melcourt Industries. It has a relatively low bulk density (around 350 g/litre, which is comparable to peat), a low pH (4.5-5.5) and a low nutrient status (electrical conductivity around 200 μS/cm). Sylvafibre is more free-draining than most peat, having an air-filled porosity of 15-23%, so it requires more frequent irrigation. There is some nitrogen (N) lock-up with Sylvafibre, in the same way as with pine bark used in substrates, therefore extra N fertiliser may be required to counteract this.

Sylvafibre is not usually used alone but gives optimum results when blended with fine bark. For this project a blend of 70% Sylvafibre and 30% Growbark (a fine-grade composted coniferous bark) was used, similar to blends used for nursery stock.

'Sinclair Peat Free Compost' (wood-, bark- and green compost-based substrate)
The precise formulation of this substrate is confidential to the manufacturers, William Sinclair Horticulture Ltd., but it is a blend of wood fibre, bark and green compost. These products have the advantage of being renewable, sustainable resources of UK origin. The material used was Sinclair Peat Free Nursery Stock Compost, supplied without any base nutrients. The structure and drainage characteristics of the blend were not very dissimilar to that of the Sylvafibre/Growbark blend, and it requires more frequent irrigation than peat in the same way. The green compost component would be expected to confer a higher buffering capacity, however, and also increases the density of the substrate. Green compost has a high pH and therefore this mix, in common with the green compost/coir blend (see below), had a higher pH than the other substrates used. However, there is no evidence that the higher pH in these types of substrates has an effect on nutrient availability in these mixes, unlike a high pH in peat substrates.

'Eco Peat-free Professional Mix' (green compost- and coir-based substrate)
This material is based on green compost, the product of controlled composting of plant material. It is now available in large quantities due to incentives for such material to be composted rather than being disposed of in land-fill sites. It is likely to be available at a competitive price, and has the advantage of being a truly recycled product and hence a sustainable material. The disadvantage of green compost is its inconsistency if not obtained from a reliable manufacturer with good quality controls. Many green composts are much more suitable for use as soil improvers than as components of a horticultural growing medium.

Eco-Composting at Bournemouth have been producing substrates based on green compost for many years, and have experience in producing compost for use in growing media. The compost used for the project – 'Eco Peat-free Professional' - had been acid-treated (with phosphoric acid) to reduce the pH, which is beneficial as many composts have a pH in excess of 8.0. It was also blended 50:50 with coir (see below) to reduce the bulk density and the salt content (conductivity). Undiluted green compost has too high a conductivity to be used as a growing medium. Coir is low in nutrients and has a lower bulk density than green compost, so is a useful diluent. Both green compost and coir have very high levels of water-soluble K, however as long as the nutrient levels in the substrate are balanced this is not a problem: a high-K substrate may even be beneficial for flowering plants. In the 2001 and 2002 experiments, 'Eco Base' was mixed with a wood-based material.

Coir

Coir or coconut fibre dust is the dust waste left from the coconut fibre processing industry in Sri Lanka, India, the Philippines and other tropical countries. The coconuts used have very thick husks with a small nut and they are soaked in water to remove the long fibres, which are used for making matting, ropes, etc. The smaller particles or dust is not useful, and has been piled in heaps outside the factories for years, some of the heaps being tens of years old. The quality of the coir dust depends on how long it has been stacked and any contamination during soaking or storage, for example with salt water or, occasionally, pathogens. It is important, therefore, to purchase coir for horticultural purposes from reliable sources. Coir is compressed into 'bricks' before transport, and is then re-constituted by wetting up when it reaches the UK. Coir can be used on its own as a peat substitute, however here it was used as a diluent with the green compost because of its useful low nutrient status (except for potassium), relatively low pH and low bulk density. There are concerns, however, over the use of coir as a peat alternative because it is not indigenous and has to be transported large distances from the countries of origin, and it is argued that it should be used locally. In reality the coir is often 'back-loaded' on ships returning from exporting goods from Europe, so fuel is not being used specifically to transport it. Benefits of coir include the fact that it promotes excellent root growth due to its high air capacity, hence it will be a useful component of non-peat growing media in the short and medium term at least.

LITERATURE REVIEW: SUBSTRATES AND FERTILISERS FOR LILIES[2]

Some recommendations on substrates and fertilisation for glasshouse lilies

UK advisory literature (Tompsett, 1984) suggested the following nutritional levels for growing lily bulbs in the glasshouse soil: pH 6.0-6.5, 40-60 mg/litre nitrogen (N), 50-70 mg/litre phosphorus (P), 350-500 mg/litre potassium (K), 40-80 mg/litre magnesium (Mg) and a conductivity not exceeding 2700 µS. Higher conductivity inhibits rooting and induces chlorosis. A typical base fertiliser application would be 3 to 4 kg/100m^2 of a 12:10:18 N:P:K compound fertiliser. When growing lilies in trays, peat limed to pH 6.5 should be used. A 10:10:18 N:P:K fertiliser should be added at a rate of 2 kg/m^3 (or 200 g/m^2 for standard forcing trays), either mixed in or applied to the surface and washed in after planting or housing (J.B.Briggs, personal communication). Alternatively, a controlled-release fertiliser can be used. Liquid feeding is most likely to benefit slower-growing cultivars, especially Orientals where a dark green leaf colour is required, and long-stemmed cultivars (J.B.Briggs, personal communication).

US recommendations for growing glasshouse lilies are given by De Hertogh (1989). The substrate should be sterile, free of harmful pesticide residues, well-drained and with a pH near 7.0 (but the pH can be in the range 5.5-7.5 for cultivars other than Easter lilies). Fluorine-induced leaf scorch is aggravated by a low pH. Substrates for bulb growing would typically consist of loamy soil mixed with additions such as peat, perlite, vermiculite or calcined clays, in a ratio of 1 part soil, 1 part peat and 1 part coarse aggregate. For pot-grown Easter (Longiflorum) lilies and cut-flower Asiatic and Oriental cultivars, liquid feeding should begin once the plants are placed in the glasshouse, and, for other cultivars grown in pots, as soon as growth begins. A feed consisting of 908 g calcium nitrate and 454 g potassium nitrate per 300 litres is used, initially weekly and then more frequently. Alternatively, a controlled-release fertiliser (e.g., Osmocote, 14:14:14 N:P:K) should be used in the substrate, supplemented when necessary with a liquid feed. Over-fertilising can lead to shorter plants (a disadvantage in growing cut-flowers but an advantage for pots).

Dutch recommendations published by the International Flower Bulb Centre (undated) provide detailed information. The following recommendations apply to growing lilies in the glasshouse soil. The pH is important for lily growing: a low pH results in excessive absorption of manganese (Mn), aluminium and iron (Fe), and a high pH results in poor uptake of P, Mn and Fe. Asiatic, Longiflorum and L/A hybrid cultivars need a pH of 6.0-7.0, and Oriental hybrids 5.5-6.5. Soil pH should be adjusted either by working in peat or using ammonium-based fertilisers or urea (to lower pH) or using lime, magnesian lime or nitrate-based fertilisers (to raise pH). In pre-planting soil analyses, the total salt level should not exceed 1500 µS and the chlorine level should not exceed 50 mg/litre. On lighter soils, well-decomposed manure (such as 1 m^3 well-rotted cow manure per 100 m^2) can be worked in before planting, but fresh manure has excessive salt levels and can cause root scorch. Farm-yard manure (FYM) should not be used on heavier soils, peat or sand should be used. P and K should be applied as straight fertilisers where indicated by soil analysis. Fluoride-containing fertilisers (such as single- or triple-superphosphate and some compound fertilisers) should not be used because of the danger of fluorine-induced leaf scorch; if a grade free of fluorine

[2] This literature review was originally presented in the First Annual Report for the project, and was updated in May 2003.

cannot be obtained, a fertiliser such as dicalcium phosphate should be used instead. N should be applied three weeks after planting, at a rate of 1 kg calcium nitrate per 100 m^2. If plants are weak, then 1 kg of a quick-release nitrogen fertiliser per 100 m^2 should be applied up to 3 weeks before harvesting, either through the irrigation system (washing off plants with clean water afterwards to avoid leaf scorch), or by hand between dry plants. This publication lists maximum values for nutrients in the glasshouse soil for planted lilies (Table R1), and a basic solution for the liquid feeding of lilies (Table R2). The salt level of irrigation water should be 0.5 mS/cm or lower (the salt level of rainwater is about 0.1 mS/cm). The chlorine level of irrigation water should not exceed 50 mg/litre.

Table R1. Acceptable values for nutrients in the glasshouse soil for lilies *

	Range of acceptable values
pH	5.5-6.0
Nitrogen	120-180 mg/litre soil
Phosphate (as P_2O_5)	100-150 mg/litre soil
Potassium (as K_2O)	150-200 mg/litre soil
Magnesium (as MgO)	75-100 mg/litre soil
Copper	10-25 mg/litre soil
Boron	0.5-1.0 mg/litre soil

* from International Flower Bulb Centre (undated)

Table R2. Basic solution for the liquid feeding lilies *

	Fertiliser per 100 litre water
Phosphoric acid (75%)	0.5 litre (0.8 kg)
Potassium nitrate (13.5/38%)	5.0 kg
Calcium nitrate (15.5%)	2.5 kg
Ammonium nitrate (35%)	5.0 kg
Magnesium nitrate (9.5/11%)	2.5 kg
Iron chelate DTPA (11%)	50.0 g
Copper chelate EDTA (14%)	10.0 g
Borax (11%)	20.0 g

* from International Flower Bulb Centre (undated)

The same publication (International Flower Bulb Centre, undated) provides the following recommendations for lilies grown in boxes and in pots. A widely used substrate consists of peat mixed with perlite (free of fluorine), sterilised rice chaff, soil or coarse sand. The peat used should consist of a mix of 40-80% 'black peat' and 20-60% 'white peat' (black peat is older, darker peat holding relatively more water and less air, while white peat is a lighter, less decomposed peat). The pH should be adjusted to 7.0 with lime. A base fertiliser containing 12:14:24 N:P:K and trace elements should be added at a rate of 0.5 kg/m^3. This potting compost may be recycled a number of time, after sterilising by steam or fungicide, but not for a prolonged time because of disease problems and the loss of structure.

Pot-grown Easter lilies have been a traditional product in the US for several decades (e.g., see White, 1940), and the advent of growth retardant treatments and of dwarf cultivars has greatly extended this application (e.g., see Buschman, 1988). For growing pot-lilies, a lightweight substrate with a pH of 6.0-7.0 should be used, such as the compost described above with 30% sand or perlite added; a base dressing of 1.0-1.5 kg Osmocote (14:14:14 N:P:K) and 1.0-2.0 kg 'sulphate of potash-magnesia' [*sic*] per m^3 should be incorporated (International Flower Bulb Centre, undated).

Fertilisers and fertigation of glasshouse lilies

In their comprehensive review on the physiology and utilisation of lilies, Beattie *et al*. (1993) stated that "Relatively few studies have examined the nutritional status of lilies during forcing". Similarly Miller (1993), reviewing the physiology of Easter lilies, presented little research on this topic. Because of the importance of Easter lilies in the US market, a high proportion of lily research has been carried out on pot-grown bulbs of these cultivars. Several workers considered that the nutrient reserves within the bulbs should be sufficient to sustain a large part of growth, although this depends on nutrition during the bulb production phase, while fertilising does have an effect on plant quality (e.g., see White, 1940). Thus McKenzie (1989) reported that the fertilisation of Asiatic cultivars during glasshouse growing was unnecessary, while Beck (1984) and Aimone (1986) wrote, respectively, that fertilisation was required only once buds were visible or shoots were 10-15 cm tall. Working with the genetic dwarf cultivars Crimson Pixie and Lemon Pixie, it was reported that there was no consistent relationship between fertiliser application and growth and flowering (Gamez, 1990). When fertigation was recommended, these workers and others (Aimone, 1986; Lewis *et al.*, 1987; McKenzie, 1989) suggested rates of 200-500 mg N per litre.

The nutrition of Easter lily cv Croft were studied in sand culture by Seeley (1950), using a full nutrient solution, solutions deficient in N, P, K, calcium (Ca), magnesium (Mg) and boron (B), and distilled water. In the –N treatment, the plants were shorter than controls, foliage was light green, and there was marked basal leaf yellowing. Without Ca, plants were short, with lighter foliage, poor roots and poor flowers that failed to develop normally or were blasted. Without Mg, the leaves became mottled, then yellow, then brown, and roots were poor. Flowering date was unaffected by treatment. Leaf burn or spotting occurred on all treatments, and the average number of leaves affected was highest with complete nutrients and in -B and –K treatments, suggesting that this disorder was not caused directly by a mineral deficiency. This contrasted with the observations of Stuart (1949), that leaf lesions appeared first where B or Mg were deficient. These contradictions may have been due to differences in pre-treatments or in concentrations and ratios of nutrients.

Miles (1952) carried out a small experiment on *L. longiflorum*. Compared with plants grown with complete nutrients, the omission of N led to weak stems, small pale leaves with chlorotic leaf tips, and later flowering, while omitting K or P resulted in smaller effects. When Ca was omitted, leaf scorch occurred, and the following year's growth was poor. When Mg was omitted, small necrotic patches (like hail damage) appeared on the leaves.

Kiplinger et al. (1972) investigated the effects of using slow-release fertilisers (Osmacote (18:9:9) or MagAmp (7:40:6)), with and without liquid feeding, on pot-grown lilies. All treatment combinations produced saleable pots, but the foliage was pale if no liquid feed was used.

Weidner (1977) investigated the growth of Mid-Century Hybrid lilies grown in a peat/sandy loam substrate. A compound fertiliser ('Poly-Crescal', 14:10:14 N:P:K) was applied at up to 3% in the base or as a weekly (up to 2%) liquid feed. A treatment of 2% in the base and 1% as a liquid feed produced the most florets and flowers and the longest stems.

Yoshiba *et al*. (1981) studied the growth of various crops in sand culture, with N supplied as nitrate or ammonium forms. Lilies grew best with 20-40% ammonium-N.

Dutch research on the fertilisation of lilies appears largely based on trials with cv Enchantment grown in peat-based substrates (such as 60% 'black peat' and 40% 'white peat' (see above) with sand added at 50 litres/m^3 and fertilisers such as PG-Mix (14:16:18 N:P:K, with trace elements)) (van der Boon *et al.*, 1983, 1986, 1987). The most important factor for high-quality flowers and good vase-life was the NPK fertiliser applied to the potting substrate, not the fertiliser applied previously in the field. For growing in pots, PG-Mix was applied at rates from 0 to 6 g/litre. The best results (on flower quality and vase-life) resulted from using 0.75-1.50 g/litre, applying half of this pre-planting and the remainder as two equal top-dressings one month apart. For early and late forcing, 0.75 and 1.0 g/litre of the fertiliser, respectively, were recommended. High amounts of fertiliser retarded emergence and flowering and reduced height.

The nutrition of Mid-Century hybrid lilies grown in a polythene-clad glasshouse was studied by Giustiniani *et al*. (1988). A high proportion of the mineral requirements was supplied by the bulbs themselves, with uptake from the substrate important only late in the growing cycle. Better quality flowers resulted from using higher rates of N and K (16 g N and 42 g K_2O per m^2).

In studies on 'semi-forced' lily cv Enchantment, the effect of planting density (operating via light levels) on plant quality (height, flower numbers, etc.) were greater than the effects of a proprietary organic fertiliser (used at rates up to 26 t per ha) (Aoki *et al.*, 1988). Bulb dry weight at flowering was, however, increased by increasing rates of the fertiliser.

Holcomb *et al*. (1992) studied the fertigation of pot-grown dwarf cvs Crimson Pixie and Lemon Pixie. Water and fertiliser use was similar when either ebb-and-flow or drip irrigation was employed. Good quality lilies were obtained when 75 mg N/litre was applied using 20:19:18, 16:4:12, 20:0:20 or 20:10:20 N:P:K feeds. There were interactions between irrigation method, fertiliser rate and cultivar on plant height. For example, Crimson Pixie was tallest using the 20:0:20 feed and shortest with the 16:4:12 feed under ebb-and-flow irrigation, but there were no differences under trickle irrigation.

Prince *et al*. (1989) studied the effects of the time of ending fertigation in pot-grown Easter lily cv Nellie White. When fertiliser application was stopped at 'visible bud' (VB) stage, increased chlorosis was seen in the post-glasshouse storage period (3 weeks at 2˚C in the dark), and this chlorosis was not alleviated when fertilisation was continued to 2 weeks after VB stage. The effects of terminating fertigation were exacerbated by treatment with the growth retardant ancymidol. It was better to continue fertigation until harvest.

Choi *et al*. (1995) grew Easter lilies, cv Ace and Nellie White, in soil-based, 'peat-lite' and peat-rockwool substrates under different rates of nutrition. Higher plant dry and fresh weights were obtained when sub-irrigated with ¼-strength nutrient solution, compared with ½- or full-strength nutrients applied via sub-irrigation or full-strength nutrients applied by hand. Sub-irrigation with full-strength fertiliser led to an accumulation of salts in the top 2 cm of the substrate.

Treder (2001) investigated the fertilising of cv Star Gazer grown on a peat/bark/sand substrate. Plants fertilised with a 15:11:9 fertiliser (0.8 or 1.6g/dm) showed increased accumulation of P, K and Mg, compared with controls.

The effect of soil salt concentration on cv Casa Blanca, grown in a polythene house, was studied by Hwang *et al*. (1998). Increasing salinity led to shorter plants and reduced bud and flower size. The critical electrical conductivity (EC) for growth was 2.8 dS/m, and the lethal EC was 10.8 dS/m. When the EC exceeded 4.4 dS/m, nutrient uptake was inhibited. Levi-Minzi *et al*. (1993) also documented the increase of soil salinity (especially due to calcium and sulphate) following the long-term cropping of lilies.

Excessive salinity is a problem with much irrigation water in the Netherlands, compounded in hydroponics by the small root volume. Sonneveld *et al*. (1999) grew lilies (cv Star Gazer and Connecticut King) and other species in hydroponics systems to ascertain their tolerance to salt. Lilies were planted in perlite in a hydroponics gutter fertigated by drip tape. A range of EC values was produced by adding salt (sodium chloride) (EC 1.8-2.8 dS/m; 0-12 mM/litre sodium chloride), and in a further treatment the highest EC was produced by the addition of plant nutrients instead of sodium chloride. The flower weights of lilies decreased with increasing salinity, for cv Connecticut King above an EC of 2.28 dS/m, and for cv Star Gazer above an EC of 1.58 dS/m. Similar effects were seen where the high EC was produced by adding nutrients. Vase-life of lilies was not affected by these treatments, but floret size decreased with increasing salinity and there were more misshapen buds. Tissue analysis showed that sodium absorption was several times higher in Star Gazer than in Connecticut King, with the reverse being true for chloride absorption. There was a salinity threshold at 2.0 dS/m, above which there was some growth reduction for all crops tested.

<u>Fertilisation of field-grown lilies</u>

For field-grown lilies the soil pH should be 6.0-7.0, and where the pH is above 7.2 there is an increased risk of trace element deficiency, iron and manganese deficiencies are a common problem, and corrective foliar sprays with chelates or manganese sulphate are required (Tompsett, 1984; Norris, 1988). A base dressing of 150 kg/ha P (as P_2O_5) and 300 kg/ha K (as K_2O) should be applied in autumn, and a top-dressing of 125 kg/ha N in spring just pre-emergence. Alternatively, 75 kg/ha N can be applied in addition in the base fertiliser (MAFF, 1984). In growing lilies in the field for cut-flower production, shorter plants are produced in heavier soils, so taller cultivars should be used (International Flower Bulb Centre, undated). Fertiliser use should be similar to that in glasshouse growing (see above), but if feed cannot be applied through an irrigation system an additional quantity of base dressing, or a slow-release fertiliser, should be applied, if the salt level of the soil will allow it (International Flower Bulb Centre, undated). Easter lily field crops require non-acidic soils high in calcium, so soils are limed (Miller, 1993). In the Pacific North-west of the US, typical fertiliser rates used are 140 kg/ha N, 280 kg/ha P_2O_5 and 200 kg/ha K_2O (Blaney *et al.*, 1967). Some of the N and K is applied in the base and the remainder is side-dressed in the spring during the time of rapid growth.

Kruijer (1982) reported on the effect of FYM (0, 75 or 150 t/ha) and calcium nitrate (0, 95, 190 or 285 kgN/ha) on field-grown *L. speciosum* cv Uchida. The application of FYM improved soil porosity and moisture holding, and produced more vigorous plants with darker green foliage. However, plants treated with high FYM or nitrate died-back early due to infection by *Cylindrocarpon destructans* (*Nectria radicicola*).

In fertiliser trials with cv Enchantment, the best growth was obtained using 75 kg/ha N, either as a single base application or as split-dose applications in May and June (van der Boon *et al*., 1983). In further work with the same cultivar, grown on sand or sandy-loam soil, different rates of N fertiliser (0-225 kg N/ha) were applied as base- or top-dressings (Niers and van der Boon, 1986; van der Boon and Niers, 1986, 1987). The response to N was greater on sand than on sandy-loam. To obtain best bulb yield, growing on sand, these authors recommended using 125-200 kg N/ha. It did not matter whether this was applied as a base- or top-dressing, but the general recommendation was to apply 75-100 kg/ha in the base and 75 kg/ha as a top-dressing, applying the top-dressing earlier if rain followed the base dressing. There was no advantage of applying the top-dressing as three or four split applications. On sandy loam, 25 kg N/ha should be applied before planting, followed by a top-dressing of 50 kg N/ha. In the latter case, there was a negative response when additional FYM was applied. For lilies grown on raised beds on a sandy clay soil, a base rate of 50 kg N/ha was satisfactory when the water content was high, otherwise 100 kg N/ha was more effective; a top-dressing of 50 kg N/ha was best applied in three split-doses in May to July. The optimum level of available N in early-July was 100-150 kg/ha in the 0-50 cm layer.

Tosi (1984) reported that Mid-Century hybrids required high levels of N, K and calcium fertilisers but low levels of P and magnesium; overall, their fertiliser requirements were low, compared with other flower-bulbs. Similarly, Ehlert *et al*. (2000)reported that lilies had relatively low P requirements: soils of a low P status (20mg P_2O_5/litre) would meet the requirement of the crop. *L. speciosum rubrum*, however, required higher nutrient levels. Slangen *et al*. (1987, 1989) investigated fertiliser rates with three Asiatic cultivars grown on sandy soil. The three cultivars responded in a similar way. The best bulb yields resulted from applying a total of 150 kg/ha N split to two, three or preferably four applications over the March-July period, but effects were very dependent on rainfall. Two fertilisation regimes were compared with non-fertilised controls in a trial with cv Gran Paradiso (Anon., 1989). The treatments were (1) a spring application of 7:14:28 N:P:K fertiliser (800 kg/ha), and (2) a spring application of superphosphate (600 kg/ha), potash (850 kg/ha) and ammonium nitrate (200 kg/ha) followed by a June application of magnesium sulphate (600-700 kg/ha). While the same number of bulbs was harvested in both treatments and in the control, the split-dose treatment gave the largest bulbs.

Gindina (1976) investigated fertiliser treatments for *L. davidii*, which has a poor response to fertilisers. After 3 years' growing, the best regime was to apply the following programme: (1) 45kg N + 60kg P_2O_5/ha at the start of growth, (2) 45kg N + 40kg K_2O/ha at the stage of vigorous growth, and (3) 45kg N + 60kg P_2O_5 + 40kg K_2O/ha at bud development.

The effects of irrigating field-grown cv Enchantment with saline water (containing 250mg Cl /litre) in May to June was investigated by Boontjes & Ploegman (1981). Bulb yield was increased by irrigation, and there was no adverse effect of using saline water.

Disorders related to nutritional factors

Leaf scorch

Leaf scorch commonly occurs in lilies: the specific causes are unknown, but it is often associated with calcium availability (Beattie and White, 1993), while many cultural factors, other than nutritional ones, may be involved (White, 1940; International Flower Bulb Centre, undated). In leaf scorch, the lower leaves become necrotic, sometimes with a semi-circular necrotic area on the margins, or dying back from the tip; a few scattered leaves may be affected, but sometimes 90% of the leaves show damage (Seeley, 1950; Seeley *et al.*, 1952). Leaf scorch is common in Easter lilies (Stuart *et al.*, 1952; Marousky *et al.*, 1977) and was first described for cv Croft (Stuart, 1949), and much of the following review refers to Easter lilies. Scorch also occurs in Asiatic cultivars (van Eysinga, 1980). Stuart (1949) reported that disease organisms could not be isolated from affected leaves, and that leaf scorch was most severe on pale, N-deficient plants and plants growing rapidly. When grown in soil, applying N reduced the amount of leaf scorch (but less so if P and K were applied simultaneously); grown in sand culture, leaf scorch appeared first on plants deprived of boron or magnesium. Hasek (1950) reported more leaf scorch when N was applied as ammonium sulphate or as a 4:12:4 N:P:K compound fertiliser, and less in non-fertilised controls and when N was supplied as monocalcium phosphate or muriate of potash; there was least leaf scorch when magnesium sulphate was applied. Roberts *et al*. (1951a, b) reported less leaf scorch when N was applied regularly during forcing, and that the previous field history of the bulbs affected the amount of scorch when the bulbs were grown on in a glasshouse. Lime applied to the soil reduced the amount of leaf scorch when high rates of manganese and aluminium had been applied (Roberts *et al*., 1951).

Seeley and Valasquez (1952) investigated the effects of different forms of N applied to bulbs growing in soil in pots. Most leaf scorch was found in controls growing in sand with no nutrients added, and all plants growing in soil with no fertiliser showed some scorch. In these experiments adding N was beneficial in reducing leaf scorch (the forms of N used were dried blood, ‘animal tankage’ and ammonium sulphate and sodium nitrate). A compound 5:10:5 N:P:K fertiliser added to the potting soil reduced the amount of leaf scorch in one year’s experiments, but increased it in another year; in the latter case, increasing the amount of fertiliser retarded growth but did not cause a further increase in leaf scorch. These authors also applied fertilisers during glasshouse growing. Applying N reduced leaf scorch, and the stage of growth at which it was applied was not important. Applying either boron (B) or magnesium (Mg) greatly increased the amount of leaf scorch, and applying N simultaneously greatly reduced the scorch induced by B or Mg. As well as lowering the pH and reducing the amount of leaf scorch, N applications also produced generally more attractive plants, with shorter internodes and darker green foliage, but high rates of fertiliser resulted in excessive stunting and poor flowers and foliage. The treatments had little or no effect on time of flowering or number of flowers. In their study, Seeley and Valasquez (1952) used a soil with low fertility. The variable effects of N reported from different studies may relate to the soil used, to seasonal differences, or to different bulb sources or prior history. Stuart *et al*. (1952) grew bulbs from 22 different sources, and recorded variable amounts of leaf scorch. This variability may be compounded by the high plant-to-plant differences in amount of leaf scorch within a treatment, observed by several workers (e.g., Seeley and Velasquez, 1952; Stuart *et al*., 1952), which could be due to differences in nutrient reserves or root development between bulbs.

Shanks *et al*. (1959) investigated the effects of pH, nutrients and pre-planting pesticide dips (to control root pathogenic fungi and nematodes) on Easter lily cv Croft. Liming, high N levels, added calcium (Ca) and low P levels all reduced the incidence of leaf scorch. Generally, pesticide treatments and the amount of damage to the root system did not correlate with the amount of scorch, although pre-planting dips in the insecticide demeton (demeton-S-methyl) increased scorch. The concentrations of N, K, P, Ca, Mg or sodium (Na) in leaves were not correlated with the amount of scorch. There were several interactions, for example, high N or P levels increased scorch in acid soil, but N was effective in reducing scorch under less acid conditions. Low N or P also increased the extent of basal leaf yellowing. Baggett (1967) found that high rates of P fertiliser were needed to achieve rapid development of seedlings, but the addition of lime was then necessary to prevent leaf scorch.

For Easter lilies, Dunham and Crossan (1959) reported that leaf scorch was decreased by higher levels of Ca and N, and increased by higher levels of K and P, and Bald *et al*. (1955) reported some similar effects. Dunham and Crossan (1959) further reported that both liming and applying N as calcium nitrate were effective in reducing leaf scorch. When N was applied as a 20:20:20 N:P:K compound fertiliser, as ammonium nitrate or, particularly, as urea, more leaf scorch resulted than when calcium nitrate was used. There was no effect on the extent of leaf scorch of steam sterilising or not sterilising the substrate, except where urea had been used as the N source, when there was more scorch using sterilised substrate. These authors considered that Ca levels were the major factor in leaf scorch, other elements affecting the disorder via their effects on Ca transport.

Stuart *et al*. (1952) investigated the effects of soil and environment on leaf scorch, also working on Croft Easter lilies. Bulbs from one source were grown in pots of soil:sand 2:1 substrate at Beltsville or soil:manure 3:1 substrate at Columbus. Various nitrogenous fertilisers were applied: different rates of a 4:12:4 N:P:K compound fertiliser, ammonium sulphate, sodium nitrate, dried blood and dried blood plus ammonium sulphate. In additional treatments, some pots were over- or under-watered. The application of aluminium or manganese – suspected as causes of leaf scorch – were without effect. Twice weekly applications of ammonium sulphate resulted in the least amount of leaf scorch at Columbus (where the pH of the soil and water were high), but gave more scorch at Beltsville (lower pH soil and water). At both locations, least scorch occurred in treatments given regular applications of compound fertiliser, but under-watered. Stuart *et al*. (1952) concluded that leaf scorch was due to ‘unbalanced nutrition’, and was worst in acid soils and largely overcome by calcium nitrate application.

In a brief report, Furuta (1961) summarised the effects of growing Easter lily cvs Croft and Ace under different levels of nutrition and in different soil mixtures. Neither of these factors affected plant growth in general, but altered the incidence of leaf scorch. In cv Croft, there were significant negative correlations between leaf scorch and the weight of roots and the Mg content of the foliage. There were positive correlations between leaf scorch and the following nutrient ratios in the leaves: N/Na, N/Mg, P/Na, P/Mg, K/Mg, (Mg/Ca)/K. Similar but weaker effects were observed in cv Ace. Despite these results, no causal relations were established and the correlation coefficients found were relatively low, and the author concluded that leaf scorch is caused primarily by factors other than nutrition.

Woltz & Marousky (1976) investigated leaf scorch and F in pot-grown Easter lily Ace. Treatments consisted of all combinations of (1) two levels of regular applications of superphosphate (containing 1.0% F), triple superphosphate (1.3% F) or dicalcium phosphate, and (2) lime to bring the pH to 5.5 – 6.5. More leaf scorch and higher levels of foliaf F were found in plants that received regular superphosphate at the lower pH. In related experiments, Marousky & Woltz (1976) grew five cultivars of lilies on a sand/peat substrate with dicalcium phosphate (1.7g/15-cm pot) plus sodium fluoride (NaF, containing 45% F, at 0.04 or 0.12g/pot) or superphosphate (1.5% F, at 3.6g/pot). The addition of NaF resulted in a severe scorch, especially of the lower leaves, and reduced flower numbers. Adding superphosphate gave similar, but less severe, symptoms. Also, Marousky & Woltz (1979) investigated these issues in pot-grown cvs Enchantment and Nova. Dicalcium phosphate (2 – 9g per 15-cm pot) or superphosphate (6g per pot) were applied, with or without dolomitic limestone (2g per pot), and fertilised with NO_3- or NH_4-N (74mg N per pot weekly). using superphosphate injured leaves, especially at the base of the stem, whereas dicalcium phosphate led to little or no leaf scorch. The level of F in the substrate were higher where superphosphate had been used, and soils with higher F levels caused more injury.

Dutch manuals (e.g., International Flowerbulb Centre, undated) include classifications of varietal susceptibility to leaf scorch in their listings. The following cultivars are listed as having considerable or high susceptibility: Côte d'Azur, Dreamland, Eurovision, Geneve, Medaillon, Mont Bland, Monte Negro, Roma, Sterling Star, Taptoe, Vada (Asiatic group) and Star Gazer (Oriental group).

Fluoride-induced leaf scorch
Some cultivars are sensitive to fluoride (F). Sickle-shaped lesions near the leaf tips develop rapidly, in 1-2 days; there is a chlorotic area between the necrotic and healthy tissue (Marousky and Woltz, 1977; Bergman *et al.*, 1983). Tizio & Seeley (1976) applied sodium fluoride (NaF) (0.12g per 15-cm pot) and (or) weekly NO_3- or NH_4-N to pot-grown Easter lily cv Ace. There was a positive correlation between NaF application and the amount of leaf scorch. However, leaf scorch occurred in the absence of NaF where N had been applied as the nitrate. Roorda van Eysinga (1974) investigated substrate F levels and leaf scorch in lilies grown in both peat and water culture. There was a positive correlation between the two, with a damage threshold of 7µgF/g DW. In water culture and peat trials, Nederpel (1979) investigated the effects of F-containing phosphate fertilisers (such as superphosphate) on Easter lilies. Simultaneous application of Ca reduced the F content of the plant and the degree of damage. Roorda van Eysinga (1980) grew cvs Sterling Star, Enchantment and Pirate in a sphagnum peat substrate, and showed that triple superphosphate at 2 or 3 kg/m^3 gave significant leaf scorch due to contamination with F, especially in cv Pirate. Maintaining a high substrate pH reduces leaf scorch. Sources of F should be eliminated, for example, by substituting dicalcium phosphate for superphosphate (R. Menhenett and G.R. Hanks, unpublished data). Of the two main Easter lily cultivars grown at the time in the US, Ace was more sensitive than Nellie White (Roberts *et al.*, 1979). When growing Ace (or other sensitive cultivars such as Sterling Star, Dominator or Star Gazer) the substrate should not contain superphosphate or perlite (De Hertogh, 1989). For very sensitive cultivars, a 1% solution of calcium chloride containing wetter (0.1% Tween 20) can be sprayed onto the plants daily once scorch is observed, but the calcium chloride must be 99% pure (De Hertogh, 1989).

Everett and Nelson (1996) listed the Liliaceae as one of the plant families more sensitive to F, the symptoms including a chlorosis of the leaf tips and margins leading to necrosis. A concentration as low as 1 ppm was reported to be sufficient to cause damage (this is the concentration in many fluoridated water supplies). To avoid damage, the pH should be maintained at 6.5-6.8, at which level F becomes bound as calcium fluoride in the substrate. Some examples of F contents in samples were listed, including samples of single superphosphate (2600 ppm), diammonium phosphate (2000 ppm), triple superphosphate (1600 ppm), slow-release fertiliser (376 ppm), perlite (17 ppm), ammonium nitrate (7 ppm) and peat (4 ppm). These authors examined five sources of perlite, and found the levels of soluble F in four was <0.2 ppm, but was 0.8 ppm in the fifth, although even this level was reduced to a safe level by a few leachings. Lily cvs Pixie Orange and Sunray were grown in mixes of these perlites with peat, using 0, 25 and 50% perlite: no F damage was seen. In another test, perlite with an F content of 1.7 ppm was mixed in equal quantities with peat, and satisfactory lily plants (cv Corsica) were produced even at a pH of 4.2. Much higher concentrations of fluorine in fertilisers were reported in an older survey (Swaine, 1962). Levels well in excess of 20,000 ppm F were reported for some fertiliser materials, and >30,000 ppm F for some rock phosphates.

Boron-induced leaf tip scorch

Boron (B)-induced scorch also occurs, with no particular cultivar susceptibility. In this case there is no chlorotic zone between necrotic and healthy tissues (Kohl *et al.*, 1960). The levels of B in the soil should be reduced. Kohl *et al*. (1961; see also Oertli, 1994) reported on the B distribution of a number of plants, including Easter lily. B accumulates in leaf margins and tips and between the veins, its concentration varying by 100-fold within a leaf. In some plants the accumulation of B as the plant ages may reach toxic levels, while young leaves on the same plant may show B deficiency.

Fluorine and boron damage

Marousky (1979) grew Easter lily cv Ace in soil with high levels of B or F. Only soil enhanced with F resulted in leaf scorch. In further work, Marousky *et al*. (1981) amended soil with (1) dicalcium phosphate + high levels of F, B or F+B, (2) superphosphate, and (3) superphosphate + B. The symptoms of B injury were chlorotic and necrotic leaf tips at the top of the plant, the basal leaves not being affected. F, or superphosphate, caused similar symptoms but in basal and upper leaves, so the two types of damage were readily distinguished.

Lithium-induced leaf scorch

Lithium (Li) is a possible cause of leaf scorch in plants (Kohl and Oertli, 1961), and Furuta *et al*. (1963) suggested it as a cause of leaf scorch in Easter lilies, carrying out experiments with pot-grown cvs Croft and Georgia. Various ions were applied as soil drenches. The application of Li increased leaf scorch, as did barium, strontium and nitrite to a lesser degree; sodium (Na) had no effect. Li application resulted in typical leaf scorch symptoms, with tip and marginal semi-circular lesions and leaf die-back, with a distinct line between healthy and damaged tissue, and the simultaneous application of Ca (but not of P) reduced the Li-induced effect. Applying B resulted in different symptoms, with leaf tips becoming brown then dying. Leaf scorch was also produced when Li (but not B) was injected directly into the leaf. Applying phosphate increased both the content of Li in the leaf and the amount of leaf scorch. Under conditions where water uptake by the roots was high and transpiration was inhibited, exudation of sap was observed on the older leaves, and salts accumulated as the water evaporated: misting plants for 5 minutes greatly reduced the Li content of leaves.

Leaf scorch caused by Botrytis elliptica

Leaf scorch (tip, margin and entire-leaf necrosis) similar to that described above is also caused by *B. elliptica* infection (Seeley, 1950; Miller, 1993). Seeley (1950) described leaf lesions in which *Botrytis* could not be isolated. McWhorter *et al*. (1951) concluded: “It is probable that a considerable portion of the injury formerly attributed to *Botrytis* blight may have been due to the physiological disease, scorch”. The condition occurred where lily crops had been effectively protected from *Botrytis* by applications of Bordeaux mixture.

Leaf blackening and flecking

Van der Boon *et al*. (1984) reported the occurrence of leaf blackening and flecking in lilies grown for bulb production, affected leaves containing less Ca than healthy leaves. Using Connecticut King, a susceptible cultivar, either lime was applied (700 – 3500kg/ha) or 100kg MgO (as kieserite) along with 2100kg CaO/ha. Increasing amounts of lime reduced the percentage of plants affected, while MgO had no effect.

Leaf scorch caused by chemical injury

Leaf scorch was also reportedly caused by nicotine fumigation (Seeley, 1950). However, this author reported that the same symptoms could also be found in plants not exposed to nicotine.

‘Tip burn’

Tip burn occurs in cv Pirate (Berghoef *et al*., 1981; Berghoef, 1986) and hybrids derived from cvs Pirate and Scout are susceptible (van Tuyl *et al.*, 1986). In tip burn there is the development of a white-grey transverse bands 1-2 cm from the tips of the lower leaves; in more serious cases, the young buds are lost and the plants fail to develop further. This damage was not caused by excess F. Tip burn is more pronounced in high humidity, plants grown without stem roots showed more severe symptoms, and the removal of the lower leaves just after unfolding decreased tip burn (Berghoef *et al*., 1981; Berghoef, 1986). Severe tip burn occurred on plants grown in hydroculture with a low Ca concentration, and higher concentrations decreased tip burn but did not prevent it. Tip burn decreased when the plants were repeatedly sprayed with solutions of calcium chloride (0.3 – 2.0%) or calcium nitrate (0.5 – 1.5%) when leaves were 20 – 50cm long, before the susceptible stage. Applying 2% calcium chloride eliminated symptoms entirely. Concentrations up to 204 mM were required, but these damaged the leaves, causing browning of the tips. Besides Ca, strontium and manganese were also effective, suggesting that instability of cell membranes is the cause of tip burn (Berghoef, 1986).

Basal leaf yellowing or senescence

The premature yellowing and loss of the basal leaves is a major factor in pot-grown Easter lily production in the US. Although symptoms can be minimised by good culture – leaf senescence can result from waterlogging, close planting and high temperatures - little is known of its physiological origins (Miller, 1993). Yellowing occurs when the inflorescence, a powerful sink, is growing rapidly, and deficiency of N at this time can cause yellowing (Miller, 1993). In prolonged cloudy weather, transpiration is reduced, so fertigation is ineffective. Top-dressing a slow-release, high-N fertiliser (e.g., urea-formaldehyde) helps maintain leaf health (Miller, 1991). However, Prince and Cunningham (1989) could find no correlation between foliar N levels and basal leaf senescence. The quality of pot-plants was assessed after 3 weeks storage at 2.2°C. Stopping fertigation at, or two weeks after, visible bud stage lead to more lower leaf chlorosis than when fertigation was continued to harvest (Prince and Cunningham, 1989). Because of the likelihood of poor watering in the retail chain, it was suggested in this case that nutrients should be depleted before distribution and that plain water was used in the last days before sending.

Leaf senescence is also related to P nutrition, the use of growth retardants and carbohydrate levels. Tsujita *et al.* (1978, 1979) showed that ancymidol drenches increased basal leaf senescence, and that high P nutrition reduced the ancymidol-induced effect. In these experiments it was reported that root rot was not a factor. The use of retardants can reduce leaf carbohydrate levels and lead to leaf yellowing in both the glasshouse and post-production phases (Jiao *et al.*, 1986; Miller and Bailey, unpublished data quoted in Miller, 1993).

Iron, nitrogen and manganese deficiency

Iron (Fe) deficiency shows as an interveinal chlorosis, especially in the rapidly growing upper parts of the plants (International Flower Bulb Centre, undated). This occurs in soils with a high pH or when soil temperatures are low. Oriental and Longiflorum cultivars and the Asiatic cultivar Connecticut King are susceptible. Where the soil pH is >6.5, iron chelate should be applied before planting sensitive cultivars, and application repeated once or twice after planting if foliage colour is poor. With a soil pH of 5.5-6.5, iron chelate should be applied once or twice after planting only, if required. The use of Fe-EDDHA and Fe-DTPA, including rates, is detailed by International Flower Bulb Centre (undated). For Oriental cultivars, the application of iron chelate at a total rate of 10-15 g/m^2, applying 2-3 g/m^2 at a time, has been recommended (J.B. Briggs, personal communication).

N deficiency shows as a more general yellowing of the foliage, not confined to the upper parts and especially affecting the lower leaves, often just before anthesis (International Flower Bulb Centre, undated). The plants may be smaller than usual, with stems light in weight, fewer buds and a tendency for leaves to yellow sooner after cropping. Adequate N should be applied initially, and an additional application of quick-release N can be applied if required. Manganese deficiency also shows as paler plants, but with mottled middle and upper foliage (International Flower Bulb Centre, undated).

Manganese damage

Koths & Gledhill (1978) applied Mn (0 – 100mg/pot weekly) to pot-grown Easter lily cv Ace. At flowering, no treatments showed scorch symptoms. Tissue levels of Mn were 1300ppm at the highest application rate. Holmes & Coorts (1980) also investigated the effects of concentrations of Mn in nutrient solutions for Easter lilies. Foliar symptoms of Mn toxicity appeared only when more than 50ppm were applied, namely shorter, lighter plants, leaf chlorosis, chlorotic mottling and leaf curling.

Zinc deficiency

Hasek & Farnham (1975) reported work investigating a growth abnormality in Easter lily Arai, thought to be due to Zn deficiency. However, application of 80ppm Zn sprays to field- and pot-grown plants were ineffective in reducing these symptoms.

Bud abortion, abscission and blasting
These floral disorders are major problems in lilies, and are associated with factors such as decreased light, waterlogging and ethylene. There are apparently no reported links with nutrition, except that Eastwood (1952) demonstrated increased bud blasting in Easter lily cv Creole when soil nitrate levels exceeded 50ppm.

Tissue levels of nutrients

Bulbs of cv Enchantment of good forcing quality were found to contain 1.1-1.4% N at harvest, and leaves in August 1.9-2.2% (dry weight basis) (van der Boon and Niers, 1983, 1987). Tissue levels of various elements were given by Anon. (1990; see Table R3, below) and by Slangen *et al*. (1987, 1989).

Table R3. Tissue analysis of field-grown lily cv Enchantment*

	Normal plants		Deficient plants	
	Leaves	Bulbs	Leaves	Bulbs
N (%)	1.04	2.12	0.73	0.45
P_2O_5 (%)	1.13	1.09	0.22	0.18
K_2O (%)	2.13	2.63	0.28	0.07
MgO (%)	0.90	0.17	0.05	0.07
CaO (%)	3.59	0.08	0.20	<0.10
Fe (mg/kg)	221	186	129	39
Mn (mg/kg)	71	17	9	7
B (mg/kg)	60	17	25	7
Cu (mg/kg)	5.1	5.7	3.0	1.6
Mo (mg/kg)	0.47	0.73	0.12	0.20

* after E. Boon, E. Jongman and H. Niers (cited by Anon., 1990)

In Easter lilies, Chaplin *et al*. (1981) reported that levels of N, P, K and zinc (Zn) in leaves decreased during the growing season, while levels of Ca, Mg and Cu increase. Nutrient levels in the bulbs of cv Croft were also reported by Roberts *et al*. (1964). In *Lilium speciosum rubrum* the following nutrient levels were found: N 10, P_2O_5 1.7, K 13.8, CaO 6.4 and Mg 0.34 (Ohkawa, 1977).

Substrates

Lilies grow well in any fertile, pathogen-free soil with a low salt content, soils with a poor structure being improved by the addition of peat, sand or manure (White, 1940; Tompsett, 1984; Norris, 1988). Sandy or silt loams are preferable. Lily bulbs used to be routinely grown in the border soil of glasshouses, but the repeated use of the same soil can lead to problems such as root-rot due to the pathogens *Pythium ultimum* and *Rhizoctonia solani*. Effective fungicide treatments are not always available to control these pathogens (e.g., see Scheffer *et al.*, 1956), requiring the use of soil sterilisation. Further, many soils in bulb-growing areas have soils of high pH. In order to circumvent these problems, growing in boxes or crates of a suitable substrate was investigated, and many lilies are now 'box-grown'. For container growing, John Innes Potting No. 1 or soil-less substrates are equally suitable (ADAS, 1984). However, the typical substrate used now in the UK and the Netherlands is peat, and little is known of the performance of glasshouse lilies in other substrates. In the US, the use of 'top soil' as a substrate for glasshouse and container-grown plants was already declining by the early 1950s, in favour of commercially prepared growing mixes (often including lightweight materials like perlite, vermiculite and sphagnum peat) (e.g., Dallon, 1987). These mixes were free of contaminants (pesticides, pests, pathogens and weed seeds), light in weight, with high air and water holding capacities, and free draining. Another important factor is the availability of locally produced materials for use in growing mixes (e.g., bark, nut shells, coconut husk, sawdust and spent compost), which may reduce costs (Dallon, 1987). This approach was also investigated in earlier HDC-funded work on substrates for bulb forcing (Hanks and Rahn, 1992).

Marshall *et al*. (1975) investigated the use of different substrates and NK rates for pot-grown lily Enchantment in relation to studies with the growth retardant ancymidol. The substrates used were 1:1 peat/sand and bark/sand, or 1:1:1 peat/bark/sand, and the fertiliser rates were 100, 200 or 300ppm NK. When grown in bark/sand substrate, stem and inflorescence length, bud number and petal length were all reduced. Peat/sand substrate gave the highest bud number, but also resulted in leaf scorch and senescent leaves. With increasing rates of liquid feed. there was progressively greater foliar injury.

Powell *et al.* (1975) investigated substrates and fertilisers for Easter lily Nellie White. Growth and flowering were both good using 2:1 soil/peat, 1:1:1 soil/peat/perlite and 1:1:1 soil/peat/rice hulls, but poor in plain peat. Fertilisers consisted of a base dressing of ‘MagAmp’ (7:40:6 N:P:K) alone or with slow-release fertiliser (‘Osmacote’, 19:0:20.5) and (or) a weekly liquid feed (25:0:25). Slow-release fertiliser and (or) weekly liquid feeding were beneficial in various substrates.

Devonald (1982) grew lilies in pots of potting mix to which 5% by weight of pulverised wood charcoal was added. This depressed growth and delayed flowering, compared with controls.

Goldsberry and Maffei (1986) grew Easter lily cv Nellie White in pots of soil-based substrate (comprising clay loam, sphagnum peat, ‘humph peat’ and perlite), ‘peat-lite’, and loose rockwool. Plant quality (including bud count and vase-life) was similar in all substrates, although plants in the soil-based substrate flowered significantly later than others.

Dallon (1987) grew Easter lily cvs Ace and Nellie White in pots using spent mushroom compost (which required standing for two years to allow leaching, weathering and decomposition), a 1:1 and 2:1 mix of mushroom compost with a proprietary potting medium, or another commercial potting mix. Fertilisation was either by adding Osmocote (14:14:14 N:P:K) or by liquid feeding with a 20:20:20 N:P:K feed at 200 ppm N. Lilies appeared to grow successfully in all four substrates (the amount of specific data presented in this paper was limited). Spent mushroom compost appeared to be a suitable component for growing mixes. There was a suggestion that using the growth retardant ancymidol with mushroom compost caused excessive dwarfing.

In an HDC-funded project (BOF 26) Hanks and Rahn (1992) evaluated the growth of box-grown lily cvs Connecticut King and Star Gazer, in a range of alternative substrates and waste materials. The standard substrates tested were baled medium-grade sphagnum peat and locally sourced bulk loose peat. The proprietary materials used were coir (coconut fibre blocks; Hensby Biotech Ltd.), bark (Cambark 100; Camland Products Ltd.), coir mix (a proprietary coir, straw and manure mix; Hensby Biotech Ltd.), granular rockwool (medium grade Grodan granules; Grodania AS) and a proprietary chopped straw (Samgran; Samgran Straw Ltd.). The locally obtained materials were: soil (local alluvial gley), shredded glazed paper (office waste) and softwood sawdust. Before use, the major nutrient levels of each material were made approximately equal to those of a standard peat substrate with PG-Mix (1 kg/m^3), by the addition of appropriate amounts of straight fertilisers. For acidic materials, the pH was adjusted to 6.5 using magnesian lime, and for alkaline materials magnesium sulphate was top-dressed after planting at a rate of 1.5 kg/m^2. The responses of the two cultivars were similar, despite their different habits. Both cultivars grown in rockwool, sawdust, paper, straw and bark developed pale foliage, presumably due to the substrates locking-up nutrients or nutrients being leached. Using rockwool, sawdust, paper, straw or soil led to delayed cropping and shorter stems. More florets aborted, in Connecticut King, when soil was used. There were other adverse effects of these substrates on floret size and on the length of lower stem with yellowing leaves. Overall, peat, coir and coir mix gave the most acceptable forcing results. Bark and sawdust also showed promise for lily growing, although appropriate liquid feeding would be required to remedy the pale foliage and basal yellow leaf zone. The other materials tested (soil, paper, rockwool and straw) all possessed high pH values, but could presumably be used in mixtures with peat or coir. In general terms it was clear that further investigations of the on-going nutrition of the plants would be able to improve crop quality in many of these alternative materials to an acceptable level. At the time, the project was not taken further, perhaps because the importance of the crop, and concerns about the use of peat, were not sufficiently appreciated. Neither the use of reduced-peat mixes nor of recycled peat was included in this study.

Lopez-Mosquera *et al*. (1994) grew cv Connecticut King in a polythene house, growing bulbs in soil, a soil-sand mix (60:40), and a soil-peat mix (*ca.* 65:35). Overall, the soil-peat mix produced the best results.

Logan *et al*. (1994) studied the effects of incorporating composted sewage sludge (CSS) on the growth of cv Nellie White. Bulbs were grown in a commercial compost mix or in 15, 25, 40 or 80% CSS mixed with 20% perlite with a balance of sphagnum peat. The optimal percentage of CSS for growth was 60%. The bulbs were also grown successfully in a substrate of 4:4:2 CSS, moss or pine bark, and perlite.

Szlachetka *et al*. (1997) studied the growth of glasshouse lilies cv Star Gazer in several substrates: soil, soil and manure (3:1), peat, bark and sand (1:1:1) and peat, bark and soil (1:1:1). In a June-flowering crops, the two peat/bark mixtures produced longer stems and a higher bud number than the soil or soil/manure mix. Also, adding macro- or micro-nutrients gave longer stems and more buds for soil and soil/manure, but not for the peat/bark mixtures. There was less effect of substrates in a winter-flowering crop.

Wu *et al*. (1999) investigated the use of cheap, local waste products as substrates for growing lily cv Casa Blanca, in this case filter cake (a by-product of sugar mills) and rice hulls. A substrate composed of limed filter cake and rice hull cake (3:1) plus “some” hog compost supplied sufficient nutrients and gave plants of as high quality, and bulb yields as good as, a substrate of vermiculite, perlite and peat moss.

Gong *et al*. (1996) studied the conditions for weaning tissue-cultured lily plants (cvs Connecticut King, Enchantment and Hinomoto). The most effective substrate consisted of equal parts of sand, peat and humus soil.

Klasman et al. (2002) investigated growing Asiatic lilies in soil, 1:1 soil/sand and 1:2:2:3 soil/rice hulls/river sand/perlite. Both cut-flower quality and bulb growth were best in the four-part mixture and poorest in the soil/sand substrate.

In the production of compact, pot-grown lilies, the choice of substrate (as well as environmental conditions) affects plant height, giving a potential way of avoiding the use of growth retardants (Buschman, 1988).

<u>Other planting factors</u>

Rooting
Lilies are shallow rooted, with the bulk of roots in the top 20 cm of soil. Slangen *et al*. (1989) reported that nutrient uptake by lilies in the field is initially low, up to mid-May, when the stem roots appear and N uptake becomes more effective. Most lilies, and all Mid-Century hybrids, produce both stem and base roots. Therefore the bulbs should be covered with 5-8 cm of substrate, otherwise quality is reduced, and containers should be at least 12-15 cm deep (Tompsett, 1984; De Hertogh, 1989; Beattie, 1993; International Flower Bulb Centre, undated). When growing in containers, lily bulbs are often planted close to the base of the container to allow good development of stem roots. In practice, shallower trays may be used (e.g., standard forcing trays 11 cm deep), placing the bulb on a 1 cm-deep later of substrate and then covering). Dual-purpose lily crates (crates used both for frozen bulb storage and for growing the bulbs), 22 cm deep, are preferred by many growers.

There is little information on the relative contribution of stem and bulb (basal) roots to growth and development (Beattie and White, 1993). In his review, White (1940) reported that he was not aware of the stem roots being removed experimentally to discover the effect of this, but observed that Easter lily bulbs planted very shallow bloomed just as well as ones with the stem roots only partly covered. Turner (1990) grew bulbs of Asiatic cultivars in 1-litre containers, with the bulbs either 2.5 cm above the bottom of the pot (to encourage stem roots) or at the substrate surface (to eliminate stem roots). When planted shallow to restrict stem roots, the number of bulb roots increased. While floret numbers and abortion were the same in both treatments, there were some other effects: notably, stem length was reduced, in three of the four cultivars tested, when stem roots were absent. Choi *et al*. (1996) planted Asiatic cultivars and *L. longiflorum* in pots, either with half the bulb exposed, only the bulb nose exposed, or 3 cm deep. In comparison with the other treatments, stem elongation was accelerated in cooled bulbs (but not in non-cooled bulbs) when the bulb was half-exposed, although final plant height was not affected. Pertuit (1973) and Pertuit and Kelly (1987) studied Longiflorum lilies planted below the substrate or initially half-exposed (and later covered with substrate), but was concerned with the effects of a lighting treatment during the cool-storage period, rather than with effects operating via rooting. Vetal *et al*. (2002) studied the effects (mainly on root growth) of growing a *L. speciosum* cultivar in different substrates: ‘agropeat’ (A), ‘soilrite’ (S), and 1:1 mixtures of A + S, A + ‘vermicompost’ (V), S + V, brick powder + V and soil + V. Growing on A and A + V produced the longest stem roots and bulb roots, respectively. The highest dry and fresh weights resulted from growing on S + V.

Irrigation

Kiplinger *et al*. (1975) investigated the effect of irrigation frequency on pot-grown Easter lilies Ace and Nellie White. Irrigation was done once or twice daily or once or twice weekly. The different irrigation frequencies did not affect flowering date, floret number or plant height. However, among plants irrigated only once weekly several had aborted buds.

Argo and Biernbaum (1994) investigated the irrigation and nutrition of Easter lily cv Nellie White grown with sub-irrigation in five peat-based media, with and without an evaporation barrier, using one water-soluble fertiliser applied independently to each medium. The substrates tested were proprietary mixes, variously composed of peat, rockwool, vermiculite, pine bark, bark ash, sand, perlite, calcined clay, absorbent gel, organic muck and polystryene, amended with limestone and fertilisers. The number of irrigations ranged from 12 to 20 and the amount of applied water ranged from 5.3 to 6.8 litres for the uncovered media treatments. When the root-medium surface was covered with a plastic saucer to act as an evaporation barrier, the average water applied was reduced by 35%, compared with the uncovered control. There were differences in substrate pH between uncovered and covered substrates, due to the different amounts of water applied. Similar macronutrient concentrations were found in the five media. The main differences in nutrient concentrations were found within the pots: the top 2.5 cm of substrate contained nutrient concentrations up to ten times higher than those measured in the remaining substrate of the same pot. Thus, with a non-leaching system, it could not be assumed that applied fertilisers would stay in the rooting zone. Covering the substrate surface reduced the stratification of fertiliser salts. In the substrate of the lower (root) zone, salt concentrations in the covered substrates were similar to those of uncovered ones, even though 36% less fertiliser was applied to the covered pots. Plants produced in all five substrates were of good quality. The chemical properties of the substrate had less effect on pH and nutrient management than on water-holding capacity and evaporation from the substrate surface.

Effects on growth retardant action

Lee & Yang (1998) studied the effects of short-term water deficits on field-grown cvs Élite and Star Gazer. Increasing the soil water deficit to –0.25MPa reduced plant height, leaf area, the duration of flowering and bulb and flower yields.

Mycorrhizas

The choice of substrate may affect the effectiveness of growth retardants, as is the case with chrysanthemums treated with ancymidol in a pine bark substrate. However, the same retardant appeared to work effectively on Easter lilies grown in a substrate based on pine bark (Larson *et al.*, 1987).

Easter lilies growing on the US West Coast were found to be infected with four species of vesicular-arbuscular mycorrhizae (VAM), increasing through the growing season until 95% of each root system was infected, but no benefits of the association were established (Ames *et al*., 1976; Ames & Linderman, 1977). Ames & Linderman (1978) inoculated glasshouse-grown Easter lilies with a mixture containing four VAMs along with fungal pathogens, using two inoculation levels and three N:P:K regimes. Inoculated plants showed less growth than controls, especially if high rates of inoculum and fertiliser were used. This growth reduction was due to a greater incidence of root rot (caused by *Fusarium oxysporum*). With lower fertiliser treatments, there was more infection by VAM. However, seedlings, which do not have food reserves, grew significantly larger than controls, and had higher tissue nutrient levels, when VAM were applied

Hao *et al*. (1991), assessing the value of VAM inoculations, considered that lilies had relatively low mycorrhizal dependence compared with the several other species tested. Working on Asiatic lilies, Lin *et al*. (1999) reported that, in an alkaline substrate, inoculation with the VAM *Glomus etunicatum* did not significantly enhance bulblet growth, whereas amendment with rice bran did. In a bran-amended substrate, dual inoculation with VAM and phosphate-solubilising bacteria gave the best growth promotion. Wu *et al*. (1999) reported that, when incubating lily scales in vermiculite, the addition of VAM enhanced bulblet growth. In further work, Wu & Lin (2000) grew oriental lilies in mixed vermiculite and perlite, inoculating them with four arbuscular mycorrhizae. In the first year the bulb crop from treated plants was lower than for the controls, although their P content was higher. In the second year, however, plants from some mycorrhizal treatments were taller and wider than the controls.

<u>Interactions with pests and pathogens</u>

Bald *et al*. (1955) investigated the link between leaf scorch and root damage due to *Rhizoctonia solani* in pot-grown Easter lily cv Croft. *Rhizoctonia*-related damage seen on commercial lily crops included smaller, paler plants, the loss of lower leaves, less florets, damaged or rotting roots and yellow areas on the bulb scales. Leaf scorch was strongly linked to root injury, and unilateral leaf lesions were explained as a consequence of the pattern of vascular tissues. Leaf scorch occurs under higher lighting levels, when a damaged root system may be unable to take up enough water for growth. In conditions of low N levels, damage to roots was due to *Rhizoctonia*, the amount of root injury being correlated with the extent of leaf scorch and bulb discoloration. Excessive levels of N led to a smaller root system and more basal leaf yellowing.

Tu *et al*. (1991, 1992) investigated the effects of substrates and amendments on the sclerotia of *Sclerotium rolfsii*, the cause of lily southern blight (a disease not established in the UK). Placing five *S. rolfsii* sclerotia in the soil within 1cm of a lily bulb produced ‘yellows’ symptoms in two weeks. The addition of N fertilisers inhibited sclerotial germination and saprophytic activity: sodium nitrite and ammonium bicarbonate completely inhibited germination at 125 and 250 ppm, respectively. The percentage of sclerotial germination was also reduced when the following amendments were added: chitin (ground crab, crab meal), chaff, ‘bagasse’, cattle manure, sawdust and compost from mushroom growing. Crab meal also suppressed saprophytic activity. Sclerotial germination and disease severity were reduced by a compound soil amendment consisting of 35% cattle manure, 10% chaff, 10% crab shell, 5% urea, 3% calcium superphosphate, 1% potassium chloride and 36% mineral salts.

Liu *et al*. (1996) studied the effects of various soil amendments on the population of bulb mites (*Rhizoglyphus* spp.) on lilies. Adding bark compost, fish-meal or guano had no effects on mite populations, whereas the mite population was doubled when animal wastes (dairy compost or organic fertiliser) were used. Mites were found in samples of the animal wastes, in bark compost and in soil, but not in peat or the other materials mentioned.

MATERIALS AND METHODS

Plant material

Lily bulbs (harvested the previous year and frozen in peat) were purchased in spring 2000, 2001 and 2002 from G.A.Verdegaal & Zonen Export bv, Noordwijkerhout, the Netherlands. It is understood that these bulbs are routinely dipped in insecticide and fungicide before 'freezing into' peat. The cultivars and grades used in the experiments were as follows:

Cultivar, cultivar group and grade (cm circumference)	*2000*	*2001*	*2002*
Brunello (Asiatic), 12-14	+	+	+
Star Gazer (Oriental), 14-16	+	+	+
Royal Fantasy (LA Hybrid), 12-14	+	+	
Snow Queen (Longiflorum), 14-16	+	+	
Élite (Asiatic) 12-14	+[a]		
Butter Pixie (dwarf Asiatic), 12-14		+[b]	
Dwarf Longiflorum, 12-14		+[b]	

[a] In subsidiary experiment
[b] In pot-plant experiment

Frozen bulbs were delivered to Horticulture Research International, Kirton in standard dual-purpose lily crates of polythene-wrapped peat, and placed in a cold store (–0.5 to -1.5ºC). When required, the bulbs were allowed to thaw slowly by opening the polythene film wrapping and increasing store temperature as shown in the table below. The crates were examined regularly, and, when the shoots of a cultivar were 1-2 cm long, the bulbs of that cultivar were extracted from the peat for planting. At this point any damaged, small or irregular bulbs were rejected. The key dates were as follows:

Year	*Delivery*	*Thawing*	*Plant and to 9°C*	*To glasshouse*
2000	03 April	2°C 29 April 5°C 02 May	03 May (Brunello) 04 May (others)	19 May (Brunello) 30 May (Royal Fantasy, Elite) 02 June (Snow Queen) 09 June (Star Gazer)
2001	09 April	2°C 10 May 5°C 13 May	14 May (Brunello) 15 May (others)	01 June (Brunello) 04 June (Snow Queen, Butter Pixie) 11 June (Royal Fantasy, Star Gazer) 15 June (dwarf longiflorum)
2002	10 April	2°C 26 April 5°C 28 April	29 April	21 May (Brunello) 27 May (Star Gazer)

Substrates and analysis

The substrates used in the project have been described in the Introduction. Samples of each of the non-amended substrates were taken for analysis, where necessary after mixing and damping in a compost mixer (see below). Three, 2-litre samples of each were used for the analysis of pH, conductivity, bulk density and concentrations of major and trace elements. One additional sample of each was taken for particle size analysis.

Substrate analysis in 2000 was carried out using the standard water extraction method on substrates as received (Johnson, 1980; Anon., 1987). In interpreting these data, note should be taken of the view that, because peat and composted organic matter ('green compost') have different nutrient-release properties, extraction using water tends to underestimate the level of some available nutrients in green compost-based substrates, compared with peat-based media (A. Rainbow, personal communication). Consequently, green compost-based substrates could be over-dosed with nutrients as a result of using conventional, water-based extraction. In 2001 and 2002, therefore, substrates were analysed using both the standard water extraction method and the DTPA/calcium chloride method. The analyses of materials as received are given in Table 1, 2-3 and 4-5 for the three experiments, respectively.

Table 1. 2000 experiment. Analysis of substrates as received determined by water extraction[1]. Values are means of three replicates (except for particle size). Figures in parenthesis are ADAS nutrient indices.

	1. Peat	*2. Peat/used peat*	*3. Used peat*	*4. Wood/bark-based*	*5. Wood/bark/ green-based*	*6. Green/coir-based*
pH	4.2	4.9	5.8	5.8	7.8	7.6
Conductivity (μS)	76 (0)	160 (1)	242 (1)	163 (1)	240 (1)	441 (3)
Density (g/l)	402	448	585	426	400	483
Major nutrients						
Phosphorus (mg/l)	<2 (0)	5 (1)	7 (1)	34 (5)	19 (4)	94 (8)
Potassium (mg/l)	8 (0)	38 (1)	77 (2)	155 (3)	202 (4)	608 (6)
Magnesium (mg/l)	4 (0)	40 (5)	74 (6)	5 (0)	6 (1)	14 (2)
Mineral nitrogen (mg/l) comprising	10	25	45	6	91	70
Nitrate as N (mg/l)	7 (0)	24 (1)	45 (2)	6 (0)	5 (0)	63 (3)
Ammonia as N (mg/l)	3 (0)	1 (0)	1 (0)	1 (0)	87 (2)	8 (0)
Calcium (mg/l)	9	40	69	21	24	48
Sodium (mg/l)	67	81	95	98	73	159
Chloride (mg/l)	60	80	99	153	187	376
Sulphate (mg/l)	20	70	115	21	12	28
Trace elements						
Boron (mg/l)	<0.10	<0.10	0.12	0.31	0.36	1.33
Copper (mg/l)	<0.10	<0.11	<0.10	0.07	0.10	0.11
Manganese (mg/l)	<0.10	0.10	0.07	0.30	0.63	0.30
Zinc (mg/l)	0.38	0.46	0.28	0.51	0.38	0.35
Iron (mg/l)	<0.50	1.03	1.40	1.47	9.80	6.10
Particle size (%)						
>20 mm	0.0	0.0	0.0	0.0	0.0	0.0
20 mm-10 mm	4.7	0.9	1.3	0.0	0.9	2.0
10 mm–5 mm	18.7	7.6	12.5	0.8	12.8	14.4
5 mm-1 mm	47.0	34.3	47.6	58.4	38.6	56.2
<1 mm	29.6	57.2	38.6	40.8	47.7	27.4

[1]This may tend to underestimate available nutrients in composted organic matter (green compost-based materials), see text.

Table 2. 2001 experiment. Analysis of substrates as received determined by water extraction[1]. Values are means of three replicates (except for particle size). Figures in parenthesis are ADAS nutrient indices.

	1.Peat	*2.Green/wood-based 1:3*	*3. Green/wood-based 1:1*	*4.Wood/bark-based*
pH	4.5	7.3	7.6	6.4
Conductivity (μS)	50 (0)	205 (1)	279 (1)	98 (1)
Density (g/l)	327	477	570	396
Major nutrients				
Phosphorus (mg/l)	<2 (0)	41 (5)	39 (5)	32 (5)
Potassium (mg/l)	7 (0)	383 (5)	460 (6)	144 (3)
Magnesium (mg/l)	2 (0)	11 (2)	15 (2)	3 (0)
Mineral nitrogen (mg/l) comprising	10	6	1	3
Nitrate as N (mg/l)	6 (0)	1 (0)	1 (0)	1 (0)
Ammonia as N (mg/l)	4 (0)	5 (0)	1 (0)	2 (0)
Calcium (mg/l)	5	54	79	17
Sodium (mg/l)	46	67	88	48
Chloride (mg/l)	40	141	215	62
Sulphate (mg/l)	15	12	14	10
Trace elements				
Boron (mg/l)	<0.10	0.52	0.64	0.29
Copper (mg/l)	<0.10	0.12	0.16	<0.10
Manganese (mg/l)	<0.10	0.73	0.67	0.40
Zinc (mg/l)	0.48	0.31	0.33	0.49
Iron (mg/l)	<0.5	3.0	3.7	3.4
Particle size (%)				
>20 mm	0.0	0.0	8.2	0.0
20 mm-10 mm	0.5	5.1	49.4	1.4
10 mm–5 mm	14.1	17.1	27.1	1.8
5 mm-1 mm	56.4	68.6	13.7	57.7
<1 mm	29.2	9.2	1.8	38.9

[1]This may tend to underestimate available nutrients in composted organic matter (green compost-based materials), see text.

Table 3. 2001 experiment. Analysis of substrates as received determined by DTPA/$CaCl_2$ extraction. Values are means of three replicates.

	1.Peat	*2.Green/wood-based 1:3*	*3. Green/wood-based 1:1*	*4.Wood/bark-based*
pH	2.8	5.5	5.4	3.7
Conductivity (μS)	2567	2257	2253	2220
Major nutrients				
Phosphorus (mg/l)	2	60	63	36
Potassium (mg/l)	13	444	578	318
Magnesium (mg/l)	139	111	130	117
Nitrate as N (mg/l)	8	10		<5
Ammonia as N (mg/l)	16	12	12	12
Sodium (mg/l)	33	52	75	40
Sulphur (mg/l)	13	8	9	6
Trace elements				
Boron (mg/l)	<0.10	0.70	0.89	0.36
Copper (mg/l)	<0.50	0.91	1.36	<0.50
Manganese (mg/l)	1.7	36.5	34.1	41.9
Zinc (mg/l)	3.5	15.6	17.4	12.5
Iron (mg/l)	18.7	78.7	100	53.8

Table 4. 2002 experiment. Analysis of substrates as received determined by water extraction[1]. Values are means of three replicates (except for particle size). Figures in parenthesis are ADAS nutrient indices.

	1. Peat			*2.Green/wood-based 1:3*			*3. Green/wood- based 1:1*			*4.Wood/bark-based*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	4.5	5.8	6.1	7.7	6.9	6.8	7.4	7.2	7.7	6.6	5.8	6.0
Conductivity (µS)	54 (0)	252 (1)	245 (1)	278 (1)	256 (1)	247 (1)	187 (1)	238 (1)	240 (1)	105 (0)	165 (1)	180 (1)
Density (g/l)	288	334	314	587	523	547	451	593	584	388	440	445
Major nutrients												
Phosphorus (mg/l)	2 (0)	40 (5)	39 (5)	39 (5)	35 (5)	39 (5)	32 (5)	32 (5)	38 (5)	39 (5)	31 (5)	40 (5)
Potassium (mg/l)	6 (0)	66 (2)	69 (2)	422 (6)	205 (4)	211 (4)	252 (5)	222 (4)	215 (4)	137 (3)	123 (3)	135 (3)
Magnesium (mg/l)	2 (0)	79 (6)	76 (6)	9 (1)	18 (3)	15 (2)	4 (0)	15 (2)	9 (1)	2 (0)	11 (2)	12 (2)
Mineral nitrogen (mg/l)	5	57	35	6	36	35	9	40	25	5	17	4
comprising												
Nitrate as N (mg/l)	4 (0)	57 (3)	33 (2)	3 (0)	35 (5)	32 (2)	2 (0)	40 (2)	3 (0)	2 (0)	17 (1)	2 (0)
Ammonia as N (mg/l)	1 (0)	< 1 (0)	2 (0)	3 (0)	1 (0)	3 (0)	7 (0)	< 1 (0)	22 (1)	3 (0)	< 1 (0)	2 (0)
Calcium (mg/l)	5	73	71	45	105	85	26	86	50	13	40	44
Sodium (mg/l)	58	110	109	110	118	129	81	124	127	47	90	105
Chloride (mg/l)	49	89	102	236	130	140	136	120	140	87	86	102
Sulphate (mg/l)	14	121	135	16	69	73	10	62	74	6	63	77
Trace elements												
Boron (mg/l)	0.11	0.53	0.53	0.58	0.86	1.01	0.41	0.74	0.74	0.25	1.09	1.41
Copper (mg/l)	< 0.10	< 0.10	< 0.10	0.11	< 0.10	< 0.10	< 0.10	< 0.10	0.18	< 0.10	< 0.10	0.13
Manganese (mg/l)	< 0.10	0.10	0.30	0.20	0.10	0.30	0.30	0.10	0.30	0.30	0.10	1.40
Zinc (mg/l)	0.17	0.33	0.36	0.33	0.23	0.32	0.29	0.28	0.39	0.34	0.39	0.51
Iron (mg/l)	< 0.5	< 0.5	< 0.5	4.3	1.6	2.1	2.4	2.7	2.8	2.0	0.7	0.9
Particle size (%)												
>20 mm	0	0	0	17.9	2.5	1.9	0	0	3.2	0	0	0
20 mm-10 mm	2.6	0.7	0.4	24.8	5.4	3.9	2.7	9.2	3.4	0	0.8	0.3
10 mm–5 mm	17.9	10.4	5.8	34	7.4	7.9	8.8	17.5	16.1	5	6.4	4.7
5 mm-1 mm	34.3	30.2	32.2	21.8	42.2	48.9	56.5	55.0	43.2	55.7	53.5	48.8
<1 mm	45.2	58.7	61.6	1.5	42.5	37.4	32.0	18.3	34.1	39.3	39.5	46.2

[1]This may tend to underestimate available nutrients in composted organic matter (green compost-based materials), see text.

Table 5. 2002 experiment. Analysis of the substrates as received determined by DTPA/$CaCl_2$ extraction. Values are means of three replicates.

	1. Peat			*2.Green/wood-based 1:3*			*3. Green/wood- based 1:1*			*4.Wood/bark-based*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	2.8	4.1	4.1	5.7	4.8	4.8	4.6	5.5	5.5	3.8	3.9	4.0
Conductivity (µS)	2490	2340	2370	2320	2350	2330	2250	2290	2290	2350	2300	2290
Major nutrients												
Phosphorus (mg/l)	1	43	41	67	56	62	60	65	65	41	38	46
Potassium (mg/l)	5	83	85	652	282	305	461	318	348	344	205	210
Magnesium (mg/l)	164	451	425	134	143	147	106	154	152	110	128	135
Nitrate as N (mg/l)	< 5	59	32	< 5	34	35	< 5	39	< 5	< 5	19	< 5
Ammonia as N (mg/l)	4	2	7	3	1	1	11	3	38	8	1	7
Sodium (mg/l)	31	74	80	77	89	95	43	97	96	21	72	81
Sulphur (mg/l)	9	120	126	7	61	65	2	55	60	1	62	72
Trace elements												
Boron (mg/l)	< 0.10	0.67	0.70	0.77	1.17	1.24	0.57	1.00	0.99	0.29	1.38	1.64
Copper (mg/l)	< 0.50	0.60	0.60	1.13	1.12	1.04	0.61	1.14	0.88	< 0.50	1.26	1.18
Manganese (mg/l)	1.1	5.7	9.8	25.4	33.7	39.4	38.9	14.4	41.1	53.4	58.9	72.7
Zinc (mg/l)	0.7	3.1	7.5	15.8	16.7	21.2	9.9	19.2	24.1	6.4	12.7	18.9
Iron (mg/l)	8.5	17.0	17.5	76.5	54.0	47.6	70.5	54.7	41.8	41.4	40.7	32.9

Amendment of substrates

Each of the substrates was amended to produce target nutrient levels (see below under Treatments) relative to the N, P and K equivalents of adding ‘PG-Mix’ fertiliser (14:16:18 N:P:K) at the recommended rate of 1 kg/m^3 to peat. On the basis of the initial analysis of the non-amended substrates (Tables 1, 2 and 4), the required quantities of ‘straight’ fertilisers were calculated and added to each substrate to give the required fertiliser rates. The fertilisers used were ammonium nitrate (34.5% N), potassium sulphate (41.5% K), di-ammonium phosphate (21% N and 23% P) and horticultural-grade single superphosphate (7.8% P). In the case of the wood/bark-based mix only, additional nitrogen (250 g ammonium nitrate /m^3) was added to compensate for the lock-up of nitrogen by bark. Magnesian lime was added where required to bring the pH to 6.5, while in high-pH substrates, where necessary (in wood/bark- and wood/bark/green compost-based mixtures), Mg was added as kieserite.

In addition, fritted trace elements (FN253A at 0.4 kg/m^3) were added to all substrate mixes. Etridiazole fungicide (0.18 kg/m^3 ‘Standon Etridiazole 35’, containing 35% w/w etridiazole) was added to all substrates in the 2000 and 2001 experiments, but was not used in the 2002 experiment in order to judge any adverse effects due to using used (re-cycled) substrates on disease levels. After making these additions, the substrates were placed in a compost mixer, broken up and enough tap water added to make a workable mix, and thoroughly mixed for 3–4 minutes. After allowing mixes to stand for 2 days at ambient temperatures in an unheated barn, 1 litre samples were taken and analysed for pH, conductivity, bulk density and concentrations of major and trace nutrients as before.

Because there are reports (see Literature Review) of damage to lilies due to levels of fluorine present as an impurity in superphosphate fertilisers, samples of fertilisers were analysed for fluorine. A sample of the PG-Mix fertiliser as used was analysed and found to contain 235mg/kg of fluorine.

Treatments

In all experiments in this project, peat (Shamrock Horticulture medium-grade Irish sphagnum peat) was used as the standard substrate for comparison. The used peat for recycling was kindly supplied by Winchester Growers Ltd., Pinchbeck, Spalding, Lincolnshire. This was an Irish sphagnum peat that had first been used, with a proportion of sand added, for forcing tulips, and had then been recycled for glasshouse lilies; during this process it had not been sterilised.

2000 experiment

In the first experiment, peat, used peat and a mixture of new and used peat were included to examine the effects of recycling, and three non-peat substrates were selected and tested as alternative products. Each was amended with the equivalent of ½, 1 or 1½ times the ‘standard rate’ of nutrients (see Table 6, below). No liquid feed was applied in this experiment. The six substrates were:

1. Peat
2. Peat and used peat (1:1 v/v)
3. Used peat
4. Wood- and bark-based mix (Melcourt Industries ‘Sylvafibre’ and ‘Growbark’, 7:3 v/v)

5. Wood-, bark- and green compost-based mix (Sinclair ‘Peat Free Compost’)
6. Green compost- and coir-based mix (Eco Composts ‘Eco Peat-free Professional’)

For each of the 18 substrate x base dressing combinations, three trays of each of Brunello, Royal Fantasy, Snow Queen and Star Gazer bulbs were planted (six trays for peat to provide double replication for the standard substrate).

In addition, a supplementary experiment was carried out, growing cv Élite in just the middle rate of fertiliser for each substrate. Élite was rejected for use in the main experiment, but was considered useful to test because it is highly prone to leaf scorch.

Table 6. 2000 experiment. Amounts of fertilisers and lime added to each substrate.

Substrate and base fertiliser level	*Additions (kg/m³)*					
	Potassium sulphate	*Single superphosphate*	*Di-ammonium phosphate*	*Ammonium nitrate*	*Magnesian lime*	*Kieserite*
Peat - low	0.166	0.188	0.088	0.122	4.750	0
Peat - medium	0.345	0.417	0.163	0.277	4.750	0
Peat - high	0.524	0.658	0.233	0.438	4.750	0
Peat/used peat - low	0.089	0	0.169	0.029	3.000	0
Peat/used peat - medium	0.267	0.117	0.243	0.186	3.000	0
Peat/used peat - high	0.446	0.355	0.314	0.345	3.000	0
Used peat - low	0	0	0.122	0	0.500	0
Used peat - medium	0.173	0	0.353	0.058	0.500	0
Used peat - high	0.353	0	0.424	0.217	0.500	0
Wood/bark-based - low	0	0	0	0.435	0.500	0.250
Wood/bark-based - medium	0	0	0.165	0.535	0.500	0.250
Wood/bark-based - high	0.154	0.216	0.237	0.695	0.500	0.250
Wood/bark/green-based - low	0	0.205	0	0	0	0.250
Wood/bark/green-based - medium	0	0.654	0	0.145	0	0.250
Wood/bark/green-based - high	0.052	0.583	0.176	0.235	0	0.250
Green/coir-based - low	0	0	0	0	0	0
Green/coir-based - medium	0	0	0	0.201	0	0
Green/coir-based - high	0	0	0.478	0.113	0	0

2001 experiment

In the second main experiment, three promising substrates were selected from the 2000 experiment for further examination. The amounts of fertiliser added were lowered, in line with the findings of the previous experiment: each substrate was amended with the equivalent of ¼, ¾ and 1¼ times the ‘standard rate’ of nutrients (see Table 7 below for amendments). Each combination was tested with and without using a liquid feed. The four substrates were:

1. Peat (see 2000 experiment)
2. Green compost and wood-based mix (Eco Composts ‘Eco Base’ and Melcourt Industries ‘Sylvafibre’), 1:3 v/v
3. Green compost and wood-based mix (‘Eco Base’ and ‘Sylvafibre’), 1:1 v/v
4. Wood- and bark-based mix (Melcourt Industries ‘Sylvafibre’ and ‘Growbark’, 7:3 v/v)

For each of the 12 substrate x base dressing combinations, six trays of each of Brunello, Royal Fantasy, Snow Queen and Star Gazer bulbs were planted, to allow three trays each grown with or without liquid feeding. Liquid feed (providing 180ppm N, 60ppm P_2O_5 and 180ppm K_2O) was applied at each watering, beginning when plants started vigorous growth.

Table 7. 2001 experiment. Amounts of fertilisers and lime added to each substrate.

Substrate and base fertiliser level	*Additions (kg/m³)*					
	Potassium sulphate	*Single superphosphate*	*Di-ammonium phosphate*	*Ammonium nitrate*	*Magnesian lime*	*Kieserite*
Peat - low	0.710	0.980	0.450	0.450	3.750	0
Peat - medium	2.500	3.180	1.180	2.030	3.750	0
Peat - high	4.320	5.820	1.870	3.650	3.750	0
Green/wood-based 1:3 - low	0	0	0.550	3.000	0	0
Green/wood-based 1:3 - medium	0	0	1.280	4.600	0	0
Green/wood-based 1:3 - high	0	0.280	1.950	6.200	0	0
Green/wood-based 1:1 - low	0	0	0.360	0.730	0	0
Green/wood-based 1:1 - medium	0	0	1.090	2.310	0	0
Green/wood-based 1:1 - high	0	1.090	1.760	3.930	0	0
Wood/bark-based - low	0	0	0.400	3.170	0	0
Wood/bark-based - medium	0	0	1.120	4.770	0	0
Wood/bark-based - high	1.010	1.840	1.810	6.370	0	0

2001 experiment with pot-grown lilies

The same 24 treatment combinations used in the main experiment (above) were tested with pot-grown bulbs of the dwarf lily cultivar Butter Pixie and a new dwarf longiflorum cultivar. There were three replicate pots for each treatment combination.

2002 experiment

In the third main experiment the same four substrates used in 2001 were examined to determine their suitability for recycling for further use. All substrates were amended with a standard rate of fertiliser equivalent to adding PG-Mix at 0.75kg/m^3 (see Table 8 below), and all were fed using the same liquid feed as in the 2001 experiment. There were three modes of usage:

1. New material
2. Material recovered from 2001 experiment and recycled
3. Material recovered from 2001 experiment, sterilised and recycled

The new material (from the same batch as used in 2001) was stored over winter in an unheated barn in the original polythene bags. Substrates recovered from the 2001 experiment were stored over winter in covered half-tonne bulk bins in an unheated barn. Substrate for sterilising was treated in an electric soil steriliser, involving heating to 90°C over 90 minutes, this being carried out one week prior to use. For each of the 12 substrate x substrate usage combinations, three trays of each of Brunello and Star Gazer bulbs were planted.

Table 3. 2002 experiment. Amounts of fertilisers and lime added to each substrate.

Substrate and usage	*Additions (kg/m^3)*						
	Potassium sulphate	*Single super-phosphate*	*Di-ammonium phosphate*	*Ammonium nitrate*	*Magnesium lime*	*Magnesium sulphate*	*Kieserite*
Peat - new	0.260	0.280	0.120	0.210	3.750	0	0
Peat - used	0.110	0	0.300	0	0.500	0	0
Peat - used + sterilised	0.100	0	0.280	0.050	0	0	0
Green/wood-based 1:3 - new	0	0	0.110	0.470	0	0	
Green/wood-based 1:3 - used	0	0	0.027	0.030	0	0	0
Green/wood-based 1:3 - used + sterilised	0	0	0.250	0.050	0	0	0
Green/wood-based 1:1 - new	0	0.450	0.150	0.230	0	0.100	0
Green/wood-based 1:1 - used	0	0	0.300	0.010	0	0	0
Green/wood-based 1:1 - used + sterilised	0	0.120	0.020	0.220	0	0	0
Wood/bark-based - new	0	0.450	0.100	0.230	0	0.100	0
Wood/bark-based - used	0	0	0.1900	0.140	0.500	0	0
Wood/bark-based - used + sterilised	0	0	0.150	0.230	0	0	0

Bulb planting and cold storage

Bulbs were planted in ‘lily crates’ (previously washed and disinfected using the horticultural disinfectant ‘Jet 5’ at the recommended rate) of approximate internal dimensions 56 cm x 36 cm x 16 cm (height to handles). A layer of substrate was placed across the base of the crate and firmed, so that the final depth of the layer was 1–2 cm. Bulbs were placed upright on this layer by hand at an even spacing. The numbers of bulbs planted per tray were 12 for Royal Fantasy and Snow Queen, 14 for Star Gazer and 16 for Brunello and Élite (15 for Brunello in 2002), corresponding to planting densities of 45, 50, 60 and 55 bulbs/m^2, respectively. After 2000, bulbs were not planted within 5cm of the edge of the crates, to minimise the number of shoots exiting via the crate sides. The bulbs were covered by further substrate, filling and firming to the base of the crate handles. Crates were labelled, watered thoroughly, and stacked in a cold store at 9ºC. Crates with different substrate mixes were stacked separately to avoid cross-contamination by nutrients (which, strictly speaking, compromised the randomisation of treatments). The crates were inspected at intervals of a few days, watered if necessary, and shoot growth checked. Once a significant number of shoots of a cultivar had appeared above the substrate, all crates of that cultivar were moved into the glasshouse (see table of dates under Plant material).

Equivalent procedures were used for the pot-plant experiment, planting three bulbs in each 13cm-diameter plastic flower-pot.

Growing the crop

A concrete-floored Venlo glasshouse at 13ºC minimum maintained day temperature and 12ºC minimum maintained night temperature, with automatic ventilation at 15ºC, was used throughout. Glasshouse temperature and relatively humidity were logged. Glasshouse shading paint was applied, and the floor washed down with disinfectant ('Jet 5') prior to use. Lily crates were placed on polythene film on the floor, in double rows with crate ends to pathways. There was discussion about placing crates on a concrete rather than a soil floor (as conventionally used), but it was concluded that the temperature and humidity implications of using a concrete or soil base were likely to be similar (D. Drakes and J.B. Briggs, personal communications). Further, temperatures from duplicate sensors placed under the crates and on the substrate surface were logged. Numerous spot checks showed that the temperature in the substrate surface was consistently 2ºC higher than that under the crates. This showed that the arrangement used was unlikely to cause problems through rooting being adversely affected by higher on-floor temperatures. The pot-plant experiment was housed on benching.

Watering was carried out according to the needs of individual crates or pots, using a hose-pipe directly onto the substrate and taking care to avoid water on the foliage or excessive wetness in the glasshouse generally. A diluter was added where liquid feed was being applied. General notes on the characteristics of the substrates were kept. Posts and string were placed around the 'beds' for crop support.

Crops were inspected at least weekly for pests and diseases. A routine programme of fungicide sprays was applied at 7-10 day intervals in June and July, as a precaution against *Botrytis elliptica*. The programme consisted of alternating sprays of chlorothalonil (as Clortosip) and dichlofluanid (as Elvaron). To control aphids, cultivars not yet in cropping were sprayed with nicotine (as XL-ALL Insecticide) on 25 July and with pymetrozine (as Chess) on 5 August in the 2000 experiment; in 2001 nicotine was applied on 12 and 18 July, and in 2002 nicotine and pymetrozine sprays were alternated at 7-10 day intervals throughout this period. All pesticides were used at standard rates and according to the manufacturers' recommendations. Pymetrozine was used as a precaution against melon-cotton aphid, *Aphis gossypii*, which can be troublesome on lilies, although, in this instance, only the glasshouse potato aphid, *Aulacorthum solani*, was encountered. Aphid identifications were made by Rosemary Collier (HRI Wellesbourne).

Post-planting and post-cropping substrate and foliage analysis

In the 2000 experiment, substrates from each treatment of one representative cultivar, Brunello, were sampled on 19 June 2000, mid-way through the growing period. For all experiments, substrates for all treatments of all cultivars were sampled towards the conclusion of the cropping periods. Substrate samples were taken from the whole depth of the substrate layer, and were analysed as described previously. Leaf samples were taken from plants of all cultivars from all substrates towards the conclusion of the cropping periods, and were analysed for % dry matter and N, Ca, K, Mg, P and Mn. Additional foliage samples were taken and analysed as required, for example when pale leaves were encountered.

Cropping

Flowers from the main experiments were cropped daily before 10:00 hours. Following discussions with growers, Snow Queen was cropped when the first bud was at right angles to the stem and beginning to swell, and the other cultivars were cropped when colour was visible on two or three buds (see Bloemenbureau Holland/VBN, 1994). Stems were cropped with a sharp knife at substrate level, placed in buckets of clean tap water, and moved to a shed promptly for recording.

Pot-plants were judged ready for 'marketing' when at least two bulbs in a pot had at least one bud showing colour along its length. The pots were recorded at this stage, watered as necessary, and moved to a non-lit cold-store (5°C) for 48 hours before shelf-life testing.

Storage and recording – cut-flowers

On the morning of cropping, stems were placed in buckets of flower food (3ml Polkon Chrysal AVBS plus one tablet Polkon Chrysal SVB per 3 litres) in a store at 3°C. However, if they were to be recorded immediately and were not required for vase-life testing, they were kept in tap water only.

The following were recorded after cropping:

- Foliage colour was scored from 1 (normal green) through 2 (pale green) to 3 (conspicuously pale)
- Number of *Botrytis elliptica*-like lesions, leaf tip scorch lesions and other lesions on leaves and bracts*
- Number of normally developing flower buds and of aborting buds
- Length of stem base bearing yellowing or dead leaves ('basal zone')
- Length of stem from cut base to base of inflorescence
- Overall length of whole stem from cut base to tip of inflorescence
- Weight of whole stem from cut base to top of inflorescence

* Marginal, often semi-circular brown lesions were recorded as '*Botrytis*-like lesions', as distinct from instances of leaf tip scorch (for illustrations, see International Flower Bulb Centre (undated), pp. A-4-25 - A-4-26). However, in incubated samples of both type of lesions, attempts to isolate *Botrytis* were not successful, although small amounts of *Penicillium* and *Trichoderma* were found in some cases. The unidentified small, rust-coloured leaf spots (found in 2000 on cv Star Gazer only) were also examined. No primary or secondary fungal pathogens were isolated from these spots, nor was there evidence of bacterial infection. These examinations and isolations were kindly carried out by Dr Tim O'Neill (ADAS Arthur Rickwood).

Following routine recording, samples of stems were taken for vase-life testing, aiming for five stems per crate taken at about the average cropping date for the crate. After initial recording, the bunch was placed in a cellophane sleeve and the 24-hour period in AVBS+SVB at 3°C completed (representing a period of storage at the growers). Bunches were then moved to a solution of Chrysal Professional (10ml per litre) and kept for a further 24h at 3°C (simulation of transport period). Buckets were moved to 18°C in the vase-life room (but not directly under lights) for 48h (simulation of display period at retailers). Finally, stems were trimmed to a workable length (not more than *ca.* 60cm, removing at least 3cm of stem in any case), and leaves that would be under the vase water were removed. Each bunch was placed in a clean glass vase with Chrysal Universal Flower Food (using 0.5 litre sachets) on the bench of the vase-life room. The vase-life room was maintained at 18°C and 65% relatively humidity, with light from a bank of cold-white tubular fluorescent lamps on for 12h per day and providing *ca.* 1000lux at flower height. Fresh air was drawn into the room at a regular rate, and Dräger indicator tubes were used at intervals to check for freedom from harmful concentrations of ethylene (none was found).

Flowers were examined daily, and the end of vase-life was recorded when more than 50% of florets on a stem presented petal tips that were beginning to shrivel or brown. The duration of vase-life was expressed as the number of days in the vase (the periods in simulated storage, transport and retail display were not included). In the first experiment with Star Gazer, no vase-life measurements were obtained as this cultivar responded adversely to the flower food used, the foliage becoming black and wilted. These observations were repeated, for this cultivar only, after the 2001 experiment, the flower food regime being as before except that SVB was used alone for the initial (grower's) storage phase, and the flower food included in the vases was Chrysal Clear Lily & Alstroemeria Flower Food (using 1.0 litre sachets).

Once all flowers from a crate had been cropped, the number of any non-productive bulbs was recorded, along with the reason for failure (e.g., blind stem or all buds aborted). Root growth was evaluated by standing the crates on end and examining the underside of representative examples.

<u>Storage and recording – pot-plants</u>

The following were recorded at the marketing stage:

- Overall height of each plant (above the substrate)
- Overall width of foliage of each plant

Any plant faults were also recorded, such as a prominent basal zone, pale foliage, and leaf scorch or *Botrytis*-like lesions.

Following storage for 48h in a non-lit cold store at 5°C, pots were moved to a bench under lights in a controlled temperature store at 18°C and 65% relative humidity. The lights were cold-white tubular fluorescent lamps providing about 500lux at plant height, and were on for 12 hours per day. Pots were placed on saucers for watering (with plain water) as needed. Shelf-life was deemed to end mid-way between the dates of first and last petal drop for each pot.

<u>Experimental design and statistical analysis</u>

The 2000 experiment (four cultivars x six substrates x three fertiliser rates) was arranged as a split-plot design, with each main-plot containing plots for a single cultivar. The three replicates of the four cultivar main-plots were arranged in an incomplete Latin square. Each cultivar occurred in each of the three rows of 'beds' along the house, but in only three of the four columns of 'beds' across the house; this slight non-orthogonality caused small adjustments to the mean values obtained, but had no impact on comparisons within a cultivar.

Each main-plot contained 21 plots, comprising a complete replicate of the substrate x fertiliser rate treatments, plus an additional plot of the 'standard' substrate (new peat) at all three fertiliser rates. The supplementary experiment with Élite (six substrates) was sited alongside the main experiment and data were analysed separately. Similar arrangements were used for the 2001 and 2002 experiments. In all cases, spare crates (or pots) of bulbs of the appropriate cultivar were placed at the ends of rows as guards.

Data were subjected to analysis of variance as appropriate. For many of the variates, data were log- or arcsin-transformed prior to analysis, to satisfy the assumption of homogeneity of variance, and in these cases the back-transformed values are also given in the tables of results and used in the histograms. Data are tabulated in full in the appendices, and the main commercially interesting effects are presented as histograms within Results. For crop data, it is important to note that the 'marginal means' presented in Appendix A are means for all treatments of a cultivar and for all cultivars for a treatment. The actual means for individual treatment combinations, presented graphically in Results, will cover a much wider range of values in most cases.

To assess the effects of treatments on the uniformity of response, within-plot standard deviations (SD) were calculated and checked for some of the important variates (stem length, weight and density). In all cases but one (see below), the size of the SD was affected by cultivar but not by any of the experimental treatments. Data for 'Brunello' and 'Snow Queen' were often more variable than those for other cultivars. The only instance of a significant treatment effect on SD was for the effect of fertiliser rate in the 2000 experiment, where low fertiliser rates resulted in lower SD values.

RESULTS: CROP PERFORMANCE

Crop performance, 2000 experiment

The main effect means (i.e. 'marginal means' for cultivar, substrate and fertiliser rate) and the statistical significance of the main effects and their interactions are summarised in Appendix A (Tables A1-A5). To illustrate the commercially important findings more conveniently, the results are also presented graphically in Figures 1-6, using non-transformed data. As expected, the cultivar had a large, and often predominant, effect on most variables.

In this experiment, almost all bulbs produced a marketable stem (grand mean, 0.98 stems/bulb). A small number of bulbs (28 out of a total of 3402) failed to produce a shoot or a marketable flower, mostly because the bulb had grown sideways out of the crate and had become distorted. Similar considerations applied to cv 'Élite' in the subsidiary experiment.

Cropping dates and cropping period

Although there were statistically significant effects due to substrate and fertiliser, virtually all the variance in cropping dates was accounted for by cultivar, and the differences in cropping date found between treatments would be commercially insignificant (Tables A1, A5). For example, the mean cropping dates for the various substrate x fertiliser treatments for 'Brunello' varied from day 202 to 205, for 'Royal Fantasy' from 214 to 217, for 'Snow Queen' from 224 to 225, and for 'Star Gazer' from 230 to 232 only.

The cropping period (days from 10 to 90% cropping) was longer in 'Brunello' than in the other cultivars. Although there were statistically significant effects of substrate on the length of the cropping period, these were also small and unlikely to be of commercial significance. There were no effects on cropping period due to fertiliser levels.

Stem length

Overall, the used peat, wood/bark and wood/bark/green substrates produced the longest stems, and the green/coir-based substrate the shortest. There was a major effect of fertiliser on stem length, with higher rates of fertiliser reducing stem length (Table A2). Cultivar Élite showed a similar response to substrates (Table A5).

Figure 1 shows the stem lengths for all treatment combinations, illustrating that the significant interactions between substrate, cultivar and fertiliser rate reveal a more complex pattern of effects. It can be seen that cv 'Brunello' was relatively unresponsive to differences in substrates and fertiliser rates. In contrast, 'Royal Fantasy', 'Snow Queen' and 'Star Gazer' all demonstrated shorter stems with the higher or highest fertiliser rates, though the responses differed between cultivars (e.g. compare the stem length response of the four cultivars grown in new peat to different fertiliser rates). Similarly, different cultivars perform differently in different substrates: for example, 'Brunello' produced long stems even in the green/coir substrate, while the other cultivars yielded short stems in this material. Treatment effects on total stem length (overall length of stem plus inflorescence) were similar to those of the stem alone.

Length of basal zone of stem
There was an extensive 'basal zone' of dead or yellowing leaves in 'Brunello', a short basal zone in 'Snow Queen', and little basal senescence in 'Royal Fantasy', 'Star Gazer' or Élite (Tables A2, A5). The main effects of substrate and fertiliser rate were not significant, although there was a significant interaction between cultivar and substrate (Figure 2). In 'Brunello', the basal zone was longest with green/coir substrate and shortest in new peat and in the two wood-based substrates. 'Snow Queen' showed the most marked differences between substrates, with the shortest basal zone in peat substrates (especially at the higher fertiliser rates) and the longest in green/coir-based substrate.

Stem weight and density
There were significant effects of both substrate and fertiliser on stem weight. The heaviest stems were produced with the wood/bark substrates, and the lightest stems with the green/coir substrate (Tables A2, A5). The heaviest stems were produced using the medium fertiliser rate. All experimental factors affected stem density. The densest stems were obtained in 'Brunello', with the wood/bark substrate, and with the high fertiliser rate.

Numbers of florets per stem
The number of viable (successfully opening) florets per stem was significantly affected by substrate, but not by fertiliser level (Tables A3, A5). In all four cultivars, the greatest number of florets was produced in plants in the wood/bark substrate, while, overall, the lowest numbers were produced in the green/coir material. This corresponded with the larger number of aborted florets in the green/coir material and the lower number in the wood/bark substrate.

Foliage colour
In 'Snow Queen', foliage was paler in colour with low nutrient levels generally, and especially using the three non-peat substrates (Figure 3 and Tables A4, A5). In the other cultivars there was little or no effect of treatments on foliage colour, which was satisfactory in these cases.

Leaf lesions numbers
The number of leaf-tip scorch lesions in 'Snow Queen' (about 5 per plant) was similar in all treatments, while in 'Star Gazer' there was a maximum of <0.5 per stem (Table A4). In 'Brunello' and 'Royal Fantasy', although the overall numbers of lesions varied considerably between these cultivars, there were clear effects of substrate and fertiliser levels on lesion numbers. There were most lesions in new peat, followed by the green/coir substrate, and fewer in the other materials. Especially in new peat, higher nutrient levels led to more lesions.

Botrytis–like lesions were principally found in 'Royal Fantasy' and 'Brunello', with fewer (<1 per stem) in the other cultivars (Table A4). As was the case for scorch lesions, more *Botrytis*–like lesions were found in new peat, especially with higher fertiliser levels (for 'Brunello', 'Royal Fantasy' and 'Snow Queen'), and also in the green/coir substrate in the case of 'Royal Fantasy'. These lesions occurred more generally in 'Star Gazer'.

As there was doubt over the identification of these two types of lesions, the total number was also analysed (see Figure 4). These totalled results followed similar trends to those just described. Lesions occurred relatively uniformly across substrates and fertiliser rates in 'Snow Queen', where numbers averaged about 5 per stem, and in 'Star Gazer', where they numbered <0.5 per stem. In ‘Brunello’ and ‘Royal Fantasy’, most lesions were found in new peat, with many more when combined with higher rates of fertiliser. There were also appreciable numbers of lesions, with these two cultivars, in the green/coir substrate. Apart from in ‘Snow Queen’, only low numbers of lesions were found using the wood/bark substrates.

The findings regarding substrates were confirmed in the scorch-prone cv Élite in a subsidiary experiment (Figure 5, Table A5). Grown in the wood/bark substrate, Élite was remarkably free of leaf lesions.

Another type of unidentified lesion occurred on ‘Star Gazer’ only (Figure 6). These were reddish-brown and were scattered across the leaf surface. The number of leaves per stem with such lesions was not clearly affected by the substrate, except that many more occurred in the highest fertiliser level using the green/coir substrate. Discussions with consultants and growers failed to suggest a cause of these lesions, which did not appear in the subsequent experiments in 2001 and 2002.

Root development
Root development was good in the wood/bark substrate and poorer in green/coir substrate. It was better in new peat than in used peat. The differences in root development were illustrated at Figure 6 of the project Annual Report for 2001.

Vase-life duration
For cultivars ‘Brunello’, ‘Royal Fantasy’ and ‘Snow Queen’, there were no significant effects of substrates or fertiliser rate on vase-life. For these cultivars, the cultivar means for vase-life were 9.0, 15.3 and 18.7 days, respectively. No data were obtained for ‘Star Gazer’, because it showed an unexpected and adverse reaction to the flower food used. The vase-life of this cultivar was tested again in the experiment in 2001.

Figure 1. 2000 experiment. Stem length for four lily cultivars in six substrates with low, medium and high fertiliser rates (1, peat; 2, peat/used peat; 2, used peat; 4, wood/bark; 5, wood/bark/green; 6, green/coir).

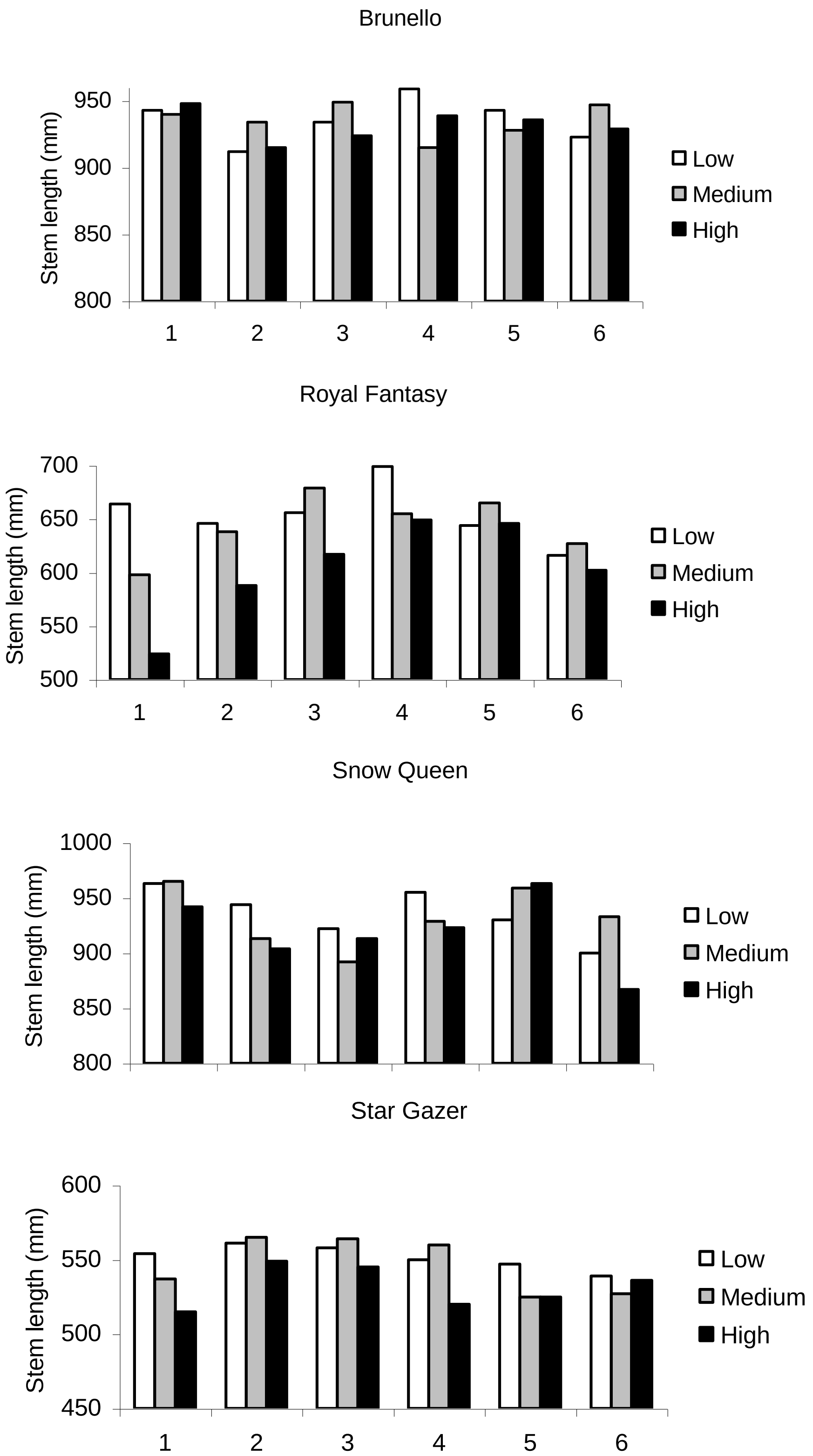


Figure 2. 2000 experiment. Lengths of basal zone of stem in cvs 'Brunello' and 'Snow Queen' in six substrates with low, medium and high fertiliser rates (1, peat; 2, peat/used peat; 2, used peat; 4, wood/bark; 5, wood/bark/green; 6, green/coir).

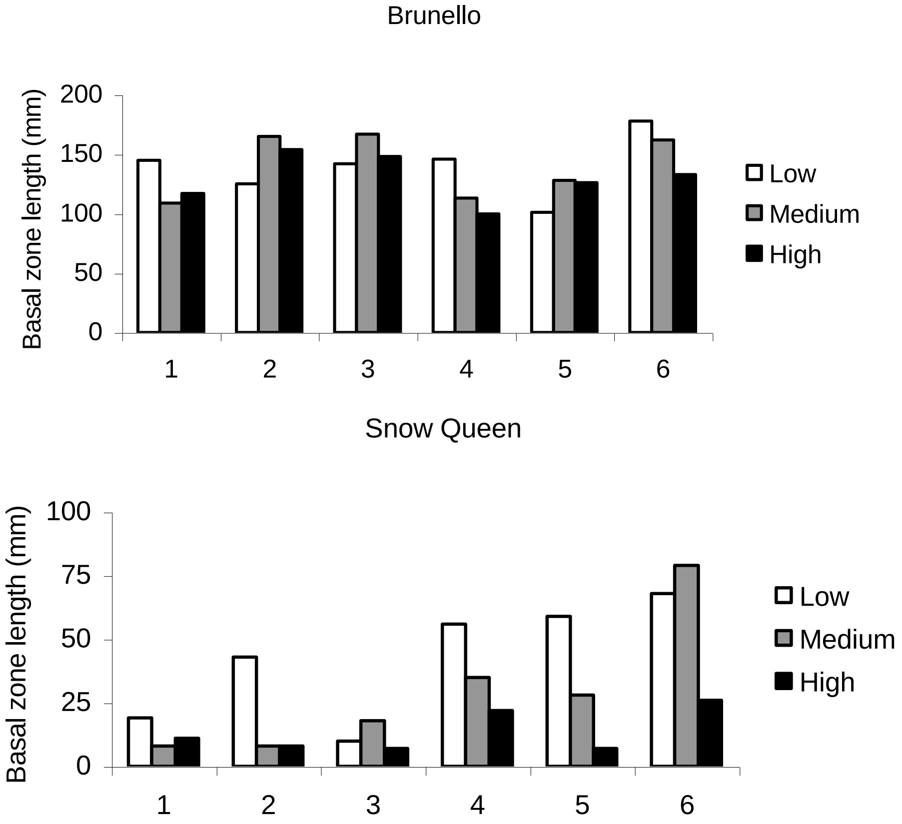


Figure 3. 2000 experiment. Foliage colour score (1, normal green; 3, very pale) for cv 'Snow Queen' in six substrates with low, medium and high fertiliser rate (1, peat; 2, peat/used peat; 2, used peat; 4, wood/bark; 5, wood/bark/green; 6, green/coir).

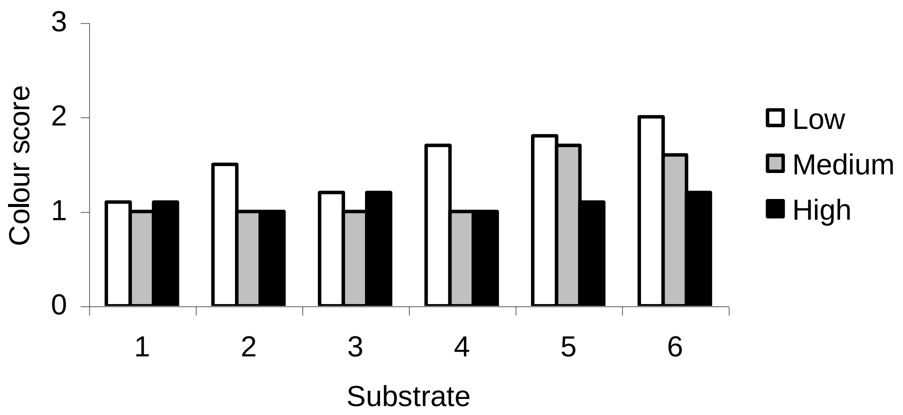


Figure 4. 2000 experiment. Total numbers of *Botrytis*-like and scorch lesions per plant for four lily cultivars in six substrates with low, medium and high fertiliser rates (1, peat; 2, peat/used peat; 2, used peat; 4, wood/bark; 5, wood/bark/green; 6, green/coir). Note the differences in vertical axes.

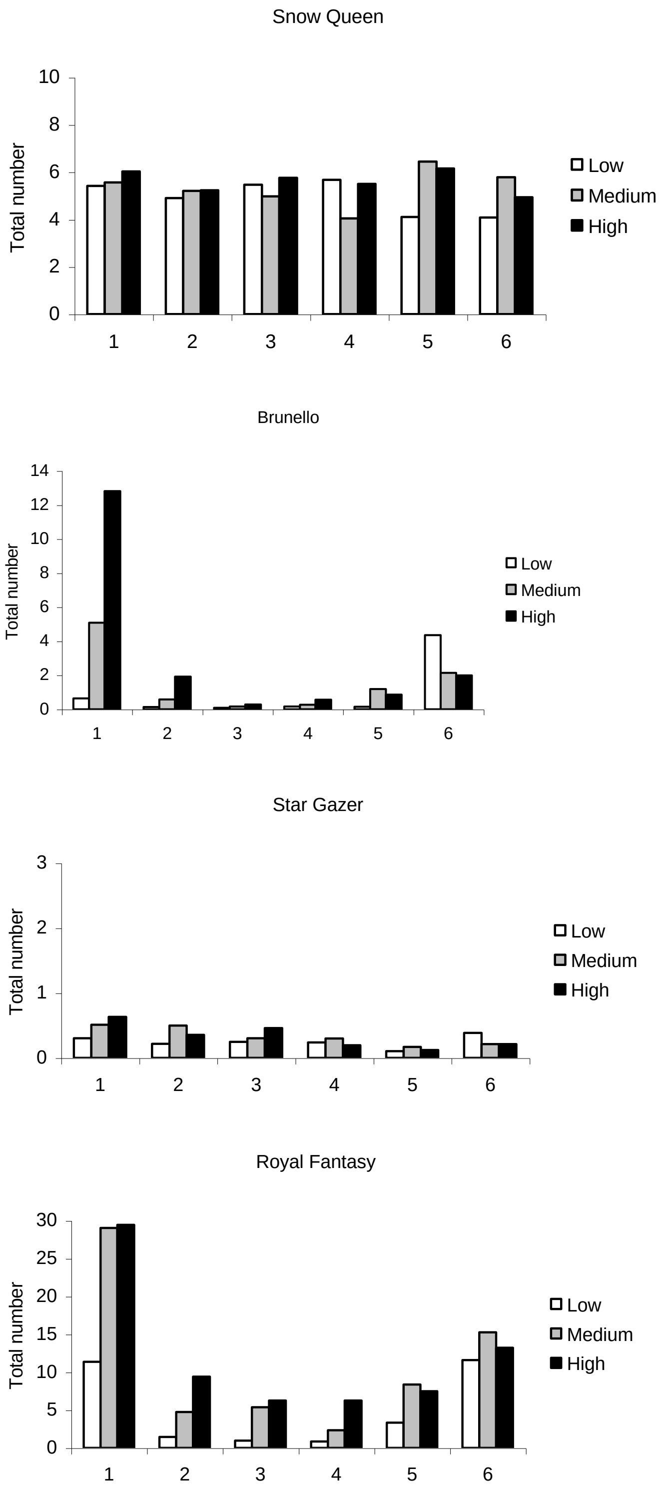


Figure 5. 2000 supplementary experiment. Total numbers of leaf lesions per plant for cv Élite in six substrates (1, peat; 2, peat/used peat; 2, used peat; 4, wood/bark; 5, wood/bark/green; 6, green/coir) at medium fertiliser rate.

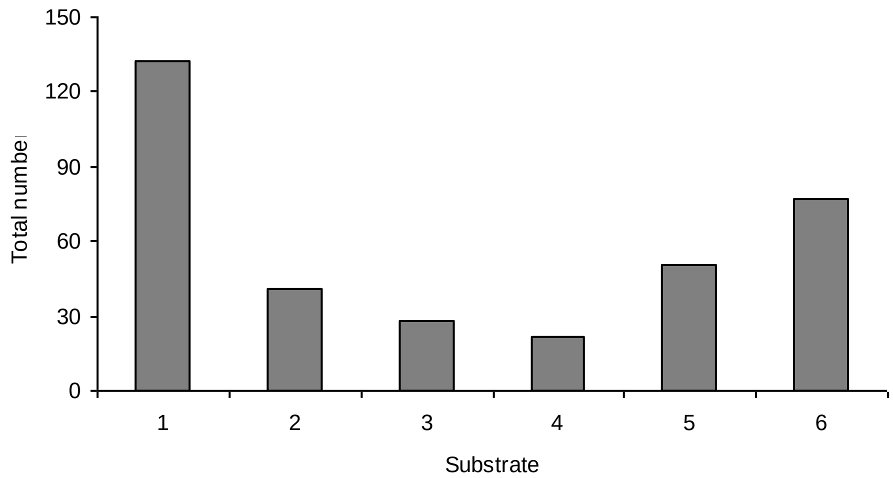
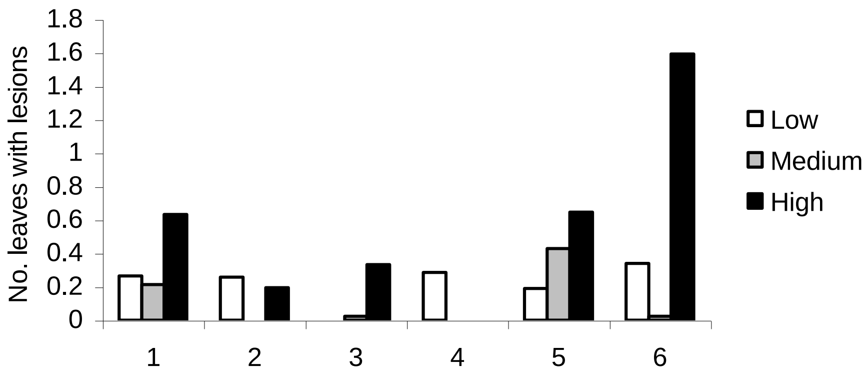


Figure 6. 2000 experiment. Numbers of unidentified lesions per plant for cv 'Star Gazer' in six substrates with low, medium and high fertiliser rates (1, peat; 2, peat/used peat; 2, used peat; 4, wood/bark; 5, wood/bark/green; 6, green/coir).



Crop performance, 2001 experiment

As for the previous year's experiment, the main effect means and the statistical significance of the main effects and their interactions are summarised in Appendix A (Tables A6-A10). The commercially important findings are presented graphically in Figures 7-10, using non-transformed data. As expected, the cultivar had a large, and often predominant, effect on most variables. Virtually all bulbs produced a marketable stem in this experiment (grand mean, 0.99 stems/bulb).

Cropping dates and cropping period

There were statistically significant effects on mean cropping date due to substrate, fertiliser and liquid feed, but differences were so small as to be commercially insignificant. Virtually all the variance in cropping dates was accounted for by cultivar (Table A6). Mean cropping dates for the various substrate x fertiliser x liquid feed treatment combinations for 'Brunello' varied only from day 209 to 210, for 'Royal Fantasy' from 218 to 219, for 'Snow Queen' from 237 to 238, and for 'Star Gazer' from 232 to 234. Variations in the dates of first and last cropping were almost entirely due to the cultivar effect.

Cropping occurred over a period of a few days in each cultivar. The cropping period (days from 10 to 90% cropping) was longest in 'Brunello' (3.5 days) and shortest in 'Royal Fantasy' (2.0 days). There were no significant effects due to the other three experimental factors.

Stem length

There was a significant effect of substrate on stem length, the wood/bark substrate producing the longest stems overall (most notably in 'Royal Fantasy') and the 1:1 mix of green/wood substrate the shortest (Table A7). The effect of base fertiliser was not significant, but plants with liquid feed were longer than those without, and there several significant interactions between experimental factors.

The full treatment means for stem length are presented in Figure 7. In peat, increasing the amount of fertiliser applied (rate of base dressing and (or) applying a liquid feed) increased stem length in 'Brunello', but decreased length markedly in 'Royal Fantasy' and to a smaller extent in 'Snow Queen' and 'Star Gazer'. In the 1:3 green/wood mix, the highest rate of fertiliser increased stem length, except in 'Star Gazer' where it reduced length. In the 1:1 green/wood mix, the response to fertiliser usage was variable, although in general increasing the fertiliser applied decreased stem length in 'Brunello' and increased it in the other cultivars. In the wood/bark substrate, the highest base fertiliser rate reduced stem length in 'Brunello' and 'Royal Fantasy', as did the use of a liquid feed in 'Star Gazer'. 'Royal Fantasy' stems were very long using lower fertiliser rates and wood/bark substrate, with or without a liquid feed.

The treatment effects on overall stem length (stem plus inflorescence) and were similar to those of the stem alone. However, the 1:1 mixture of green/wood substrate produced markedly shorter total lengths, indicating an adverse effect of that treatment on inflorescence development or extension.

Length of basal zone of stems

There was a long basal zone in 'Brunello' (overall mean of 109mm), but only short basal zones (5-8mm) in the other cultivars. Overall, the effect of fertiliser was again not significant, while using a liquid feed reduced the length of the basal zone, and there were several significant interactions between experimental factors (Table A7). In 'Brunello' (Figure 8), there was a large effect of substrate on basal zone length. There were long basal zones in plants grown without liquid feed in either green/wood substrate mixes (either ratio) or wood/bark substrate. The basal zones were short in plants in peat (irrespective of fertiliser regime) and in the alternative substrates especially with liquid feeding and some of the higher fertiliser rates. Thus there were, in this cultivar, strong effects of fertiliser rate in the alternative substrates but not in peat.

Stem weight and density

There were significant effects of substrate, fertiliser and liquid feed on stem weight (Table A7). Almost all first- and second-order interactions were statistically significant, presenting a complex pattern of effects that are illustrated in Figure 9, although in all cases there was benefit of using a liquid feed and the medium or high base fertiliser rates. The heaviest stems overall were produced with the wood/bark substrate, and the lightest with the 1:1 mix of green/wood substrate, the other materials producing intermediate results. However, increasing the amount of fertiliser applied (either by increasing rate of base fertiliser of by using a liquid feed) consistently produced significantly heavier stems. All experimental factors affected stem density. The densest stems were obtained in 'Brunello', with the wood/bark substrate, and with the high fertiliser rate.

Numbers of florets per stem

The number of viable (successfully opening) florets per stem was significantly affected by all four experimental factors (Table A8). 'Brunello' produced the greatest number of florets. For the substrates, the wood/bark produced most viable florets, and the 1:1 mix of green/wood substrate the least. The number of florets increased with an increasing level of fertiliser and when liquid feed was applied. Few aborted florets occurred in this experiment (overall mean, 0.1 per stem).

Foliage colour

The foliage colour of 'Star Gazer' was less affected by the treatments than that of the other cultivars (Table A9). Growing in peat and wood/bark substrate resulted in greener foliage than in the green/wood substrates. Increasing fertiliser levels and using a liquid feed improved foliage colour.

Leaf lesion numbers

Cultivars differed in the number and distribution of lesions (Table A9). Figure 10 shows the different responses of the four cultivars. 'Brunello' and 'Royal Fantasy' had many lesions grown in peat, a few in wood/bark substrate, and virtually none in the green/wood mixes. 'Snow Queen' had most lesions in peat and the wood/bark mix, and significant numbers in the green/wood mixtures. In these instances, there was a clear increase in lesion numbers when the fertiliser rate was increased, and sometimes applying a liquid feed also increased lesion numbers. In 'Star Gazer' there were virtually no lesions, except when grown in the wood/bark mix under the highest fertiliser regime.

Recording only ‘scorch’ lesions, the findings were the same as for total number of lesions, except that numbers were more generally increased when liquid feed was used (Table A10). *Botrytis*–like lesions were principally found in ‘Royal Fantasy’ and ‘Brunello’, with fewer in ‘Snow Queen’ and ‘Star Gazer’; otherwise, the effects of treatments were the same as for total lesion numbers.

Vase-life

Only ‘Star Gazer’ was tested in 2001, using a different flower food treatment as the cultivar had been adversely affected by the flower food used in the previous experiment. However, there were no significant effects of treatments on its vase-life, which averaged 13.5 days.

Figure 7. 2001 experiment. Stem length for four lily cultivars in four substrates with low, medium and high fertiliser rates, with (+ in legend) or without liquid feed.

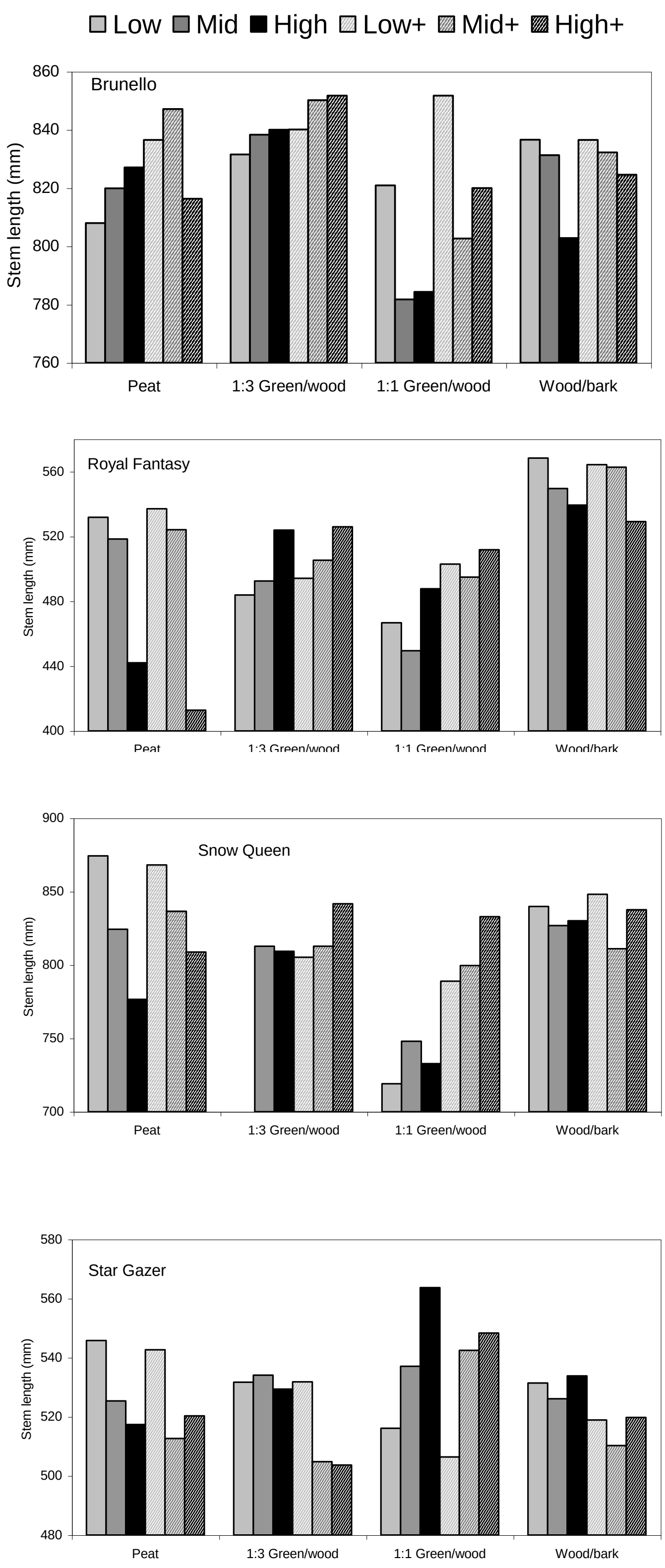


Figure 8. 2001 experiment. Length of basal stem zone for cv 'Brunello' in four substrates with low, medium and high fertiliser rates, with (+ in legend) or without liquid feed.

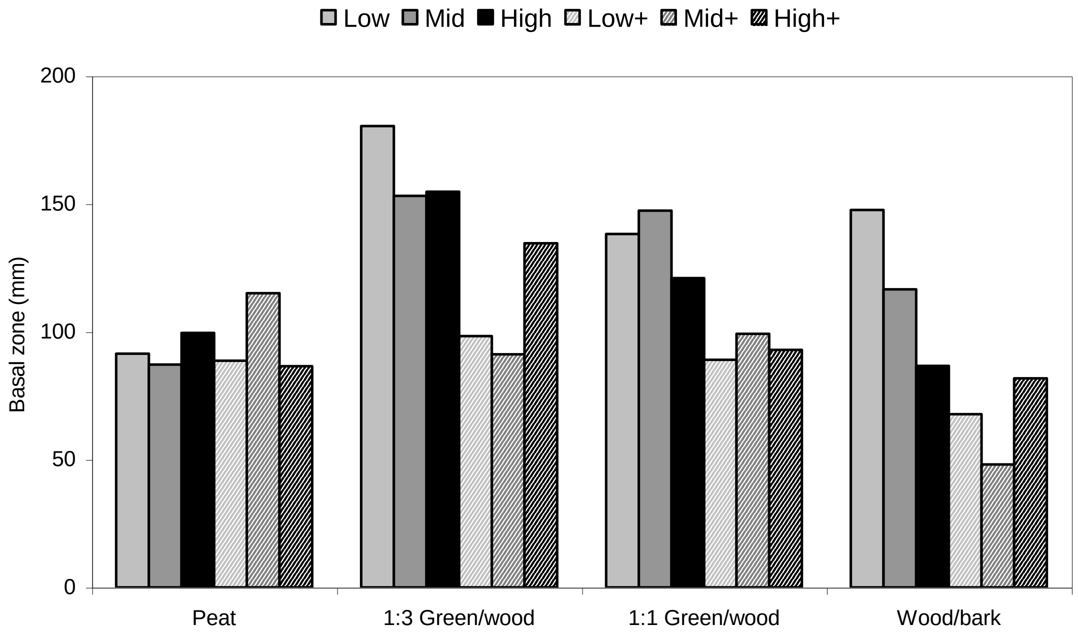


Figure 9. 2001 experiment. Stem weight for four lily cultivars in four substrates with low, medium and high fertiliser rates, with (+ in legend) or without liquid feed.

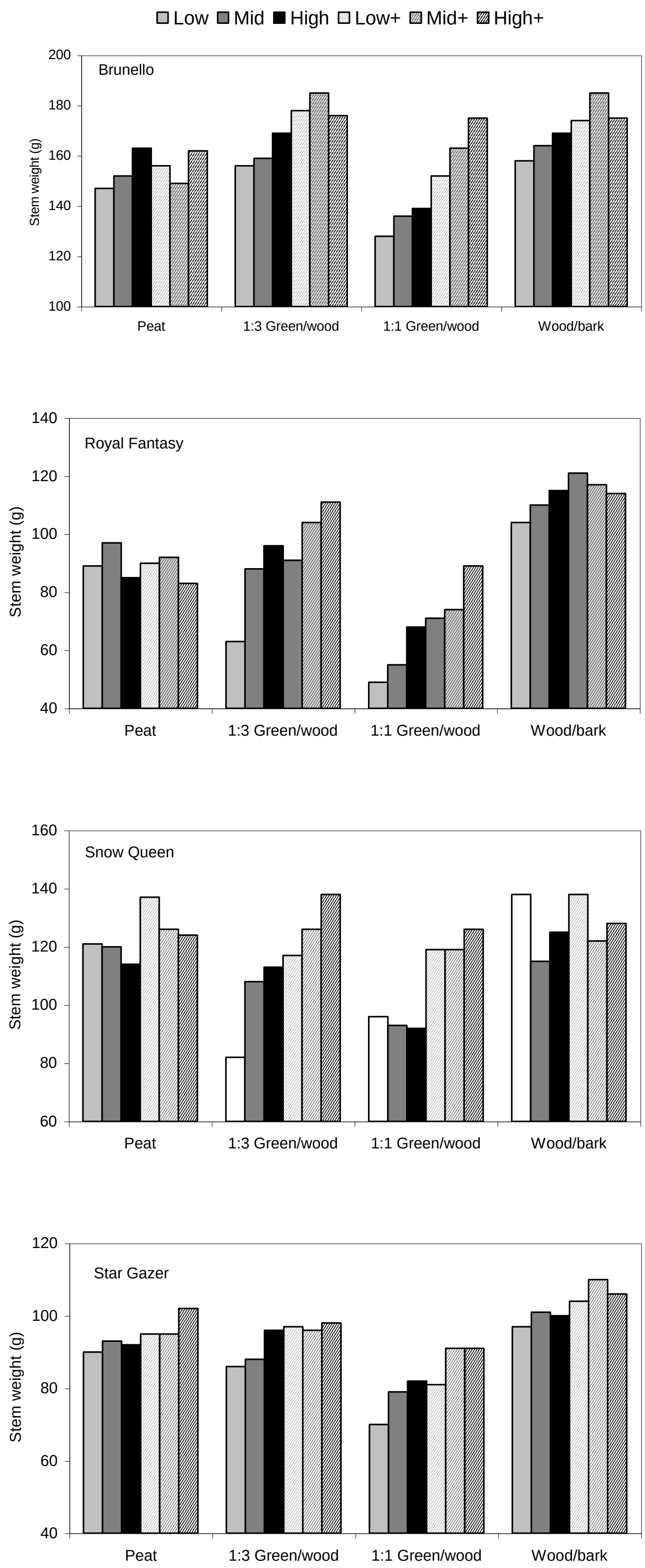
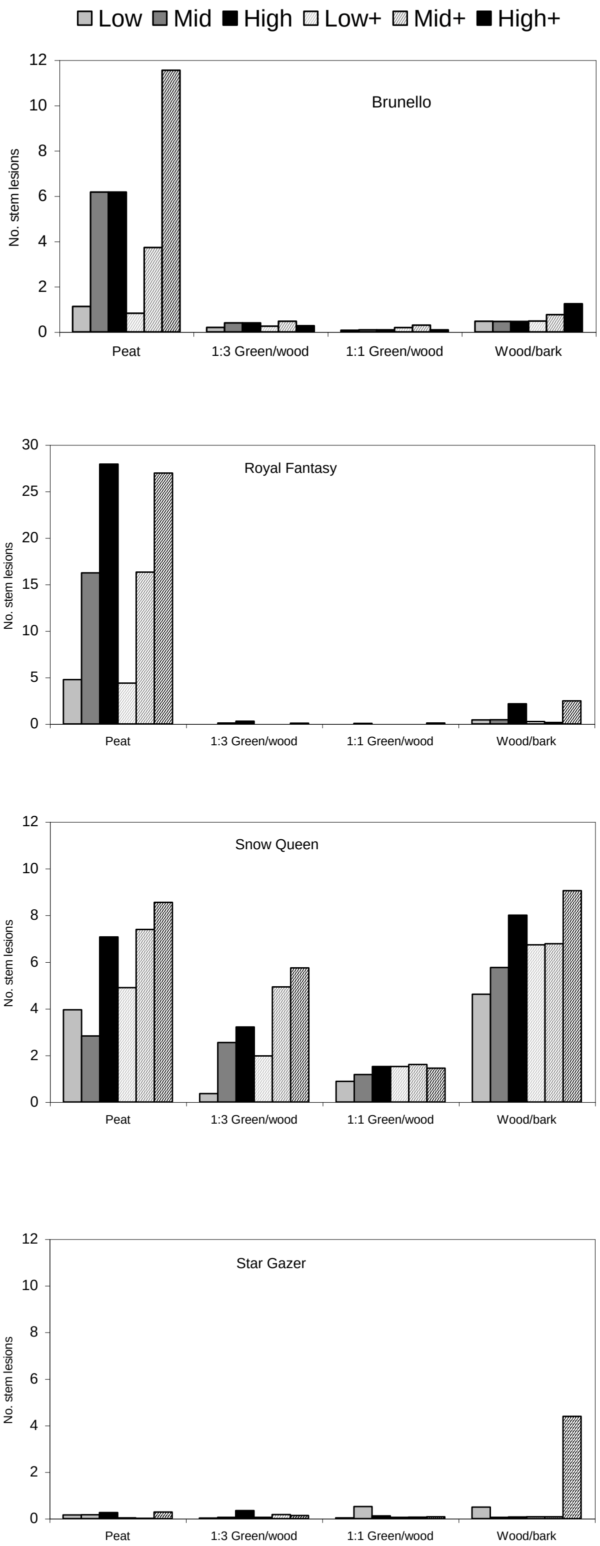


Figure 10. 2001 experiment. Total number of leaf lesions for four cultivars in four substrates with low, medium and high fertiliser rates, with (+ in legend) or without liquid feed. Note difference of vertical scale for 'Royal Fantasy'.



Crop performance, 2002 experiment

Appendix Tables A11-16 summarise the main effect means (i.e. 'marginal means' for cultivar, substrate and substrate usage (new, used or sterilised)) and the statistical significance of the main effects and their interactions. As expected, cultivar had a large, often predominant, effect on most variables. Results of the more commercially important findings are presented graphically in Figures 11-14, using non-transformed data. As in previous experiments, virtually all bulbs produced a marketable stem (grand mean, 0.96 stems/bulb).

Cropping dates and cropping period
Virtually all the variance in cropping dates was accounted for by cultivar (Table A11). Although the effects of substrate and substrate usage, and all their interactions, were statistically significant for mean cropping date, these differences were too small to be of commercial relevance. Variations in the dates of first and last cropping were entirely due to the cultivar effect. The 1-day greater spread of cropping in 'Brunello' was statistically significant, but there were no other appreciable differences.

Stem length
Stem and total stem length differences were largely accounted for by varietal effects, with a significant effect also due to substrate, but not substrate usage (Table A12). Figure 11 shows the inconsistency between stem lengths using new, used and sterilised used substrates. Overall, stem lengths were similar in all substrates with 'Brunello', whereas with 'Star Gazer' stems were shorter in peat and 1:3 green/wood mix than in 1:1 green/wood mix and wood/bark mix.

Length of basal zone of stem
There was a significant length of basal zone only in 'Brunello' (Table A12). Figure 12 shows that in 'Brunello' the length of basal zone was consistent, except in new, 1:1 green/wood substrate, where the length of the yellowing zone was doubled. In 'Star Gazer' there was virtually no basal leaf yellowing, but growing in new, 1:1 green/wood substrate mean basal zone length exceeded 25mm.

Stem weight and density
There were significant effects of substrates and of interactions between substrate, substrate usage and cultivar (Table A12). Figure 13 shows the lighter stems of 'Brunello' grown in peat, compared with other combinations. In 'Brunello', stem weight was much reduced when grown in new 1:1 green/wood mix, and this substrate also resulted in somewhat lighter stems in 'Star Gazer'. Effects on stem density followed the same trends.

Numbers of florets per stem
'Brunello' produced more viable florets per stem than 'Star Gazer', and there were fewer florets using 1:1 green/wood substrate (Table A13). The effect of substrate usage was not significant. Few aborted florets were recorded in this experiment, so no firm conclusions could be drawn.

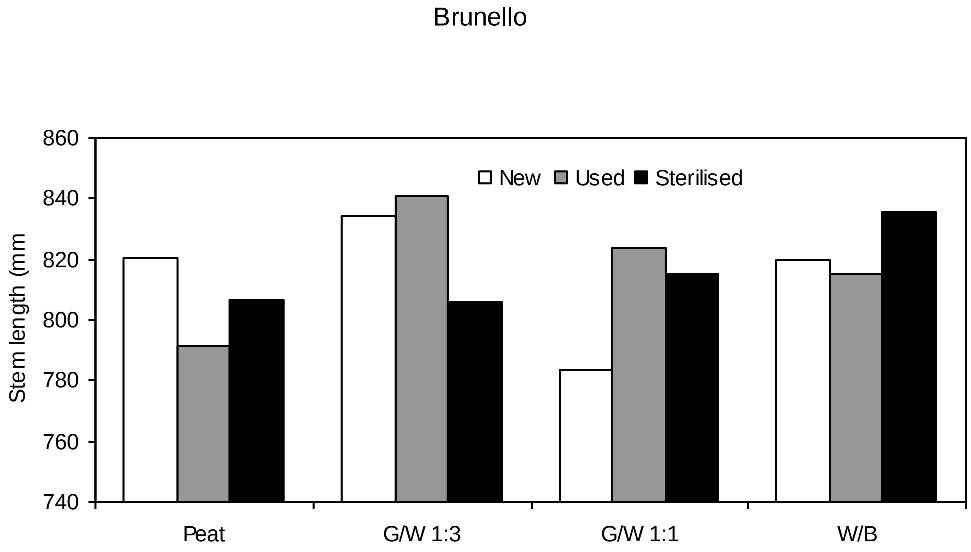
Foliage colour
The foliage was very pale in plants grown in new 1:1 mix of green/wood substrate, and especially so in 'Brunello' (Table A14). The foliage in other substrates was a normal colour.

Leaf lesions
Overall, there were more leaf lesions in 'Brunello' than in 'Star Gazer', and more in peat and wood/bark substrates than in green/wood mixes. Virtually all the interactions between the experiment factors were highly significant (Table A14). For 'Brunello', most lesions were found in new peat and new wood/bark substrate, with smaller numbers in the same substrates when recycled with or without sterilising, and in new green/wood mixes (Figure 14). For 'Star Gazer', most lesions occurred in recycled wood/bark substrates.

Recording only 'scorch' lesions, the findings were the same as for total number of lesions (Table A15). 'Brunello' also had more *Botrytis*-like lesions than 'Star Gazer'. However, in this case, most lesions were produced in peat-grown plants, and least using the green/wood mixes.

Vase-life duration
'Star Gazer' blooms had longer vase-lives that those of 'Brunello', 13.4 days against 10.9 days. However, there were no significant effects of treatments (Table A15).

Figure 11. 2002 experiment. Stem length for cvs 'Brunello' and 'Star Gazer' in four substrates either new, used or sterilised used. G/W = green/wood, and W/B = wood/bark, substrates.



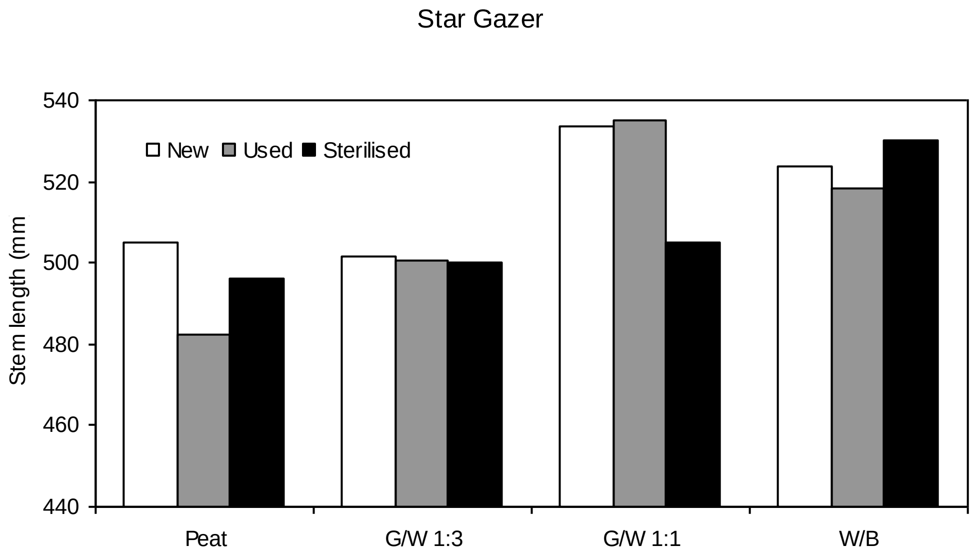
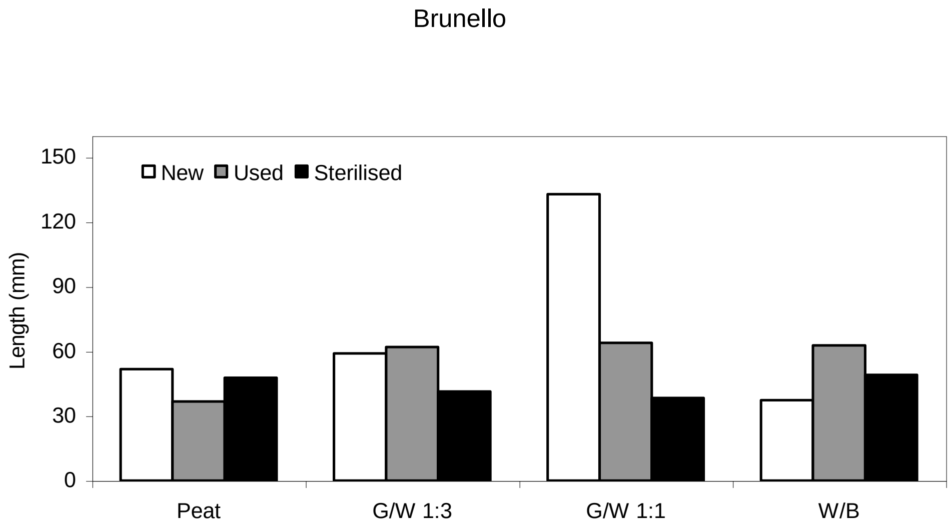


Figure 12. 2002 experiment. Length of basal stem zone for cvs 'Brunello' and 'Star Gazer' in four substrates either new, used or sterilised used. G/W = green/wood, and W/B = wood/bark, substrates. Note difference of scale of vertical axes.



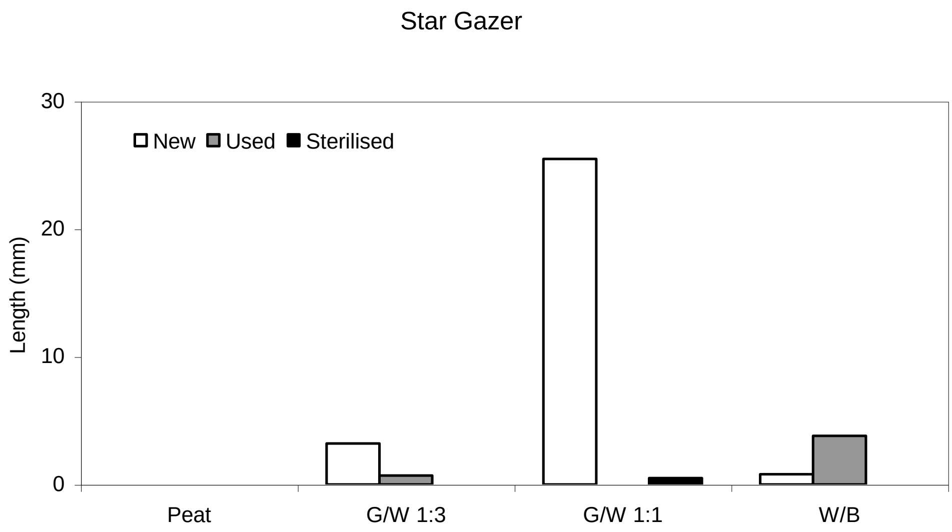
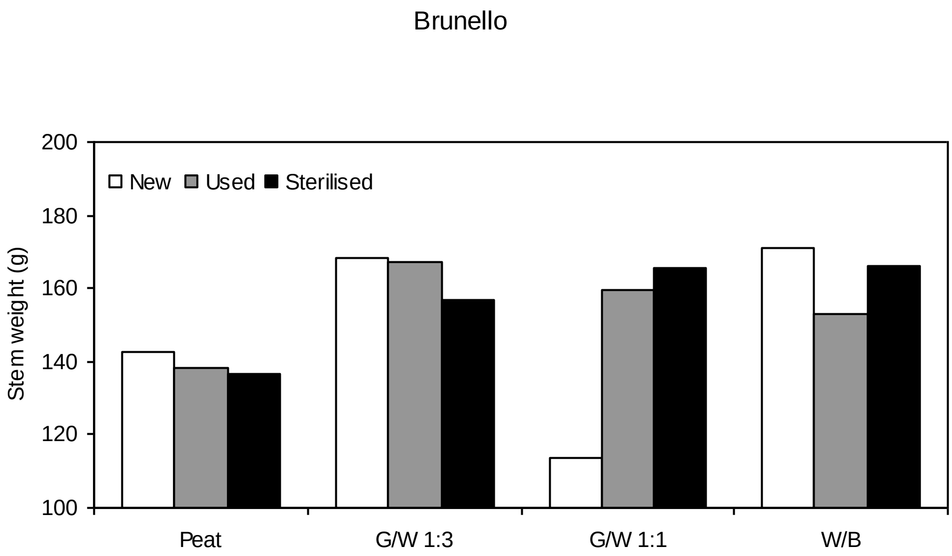


Figure 13. 2002 experiment. Stem weight for cvs 'Brunello' and 'Star Gazer' in four substrates either new, used or sterilised used. G/W = green/wood, and W/B = wood/bark, substrates. Note difference of scale of vertical axes.



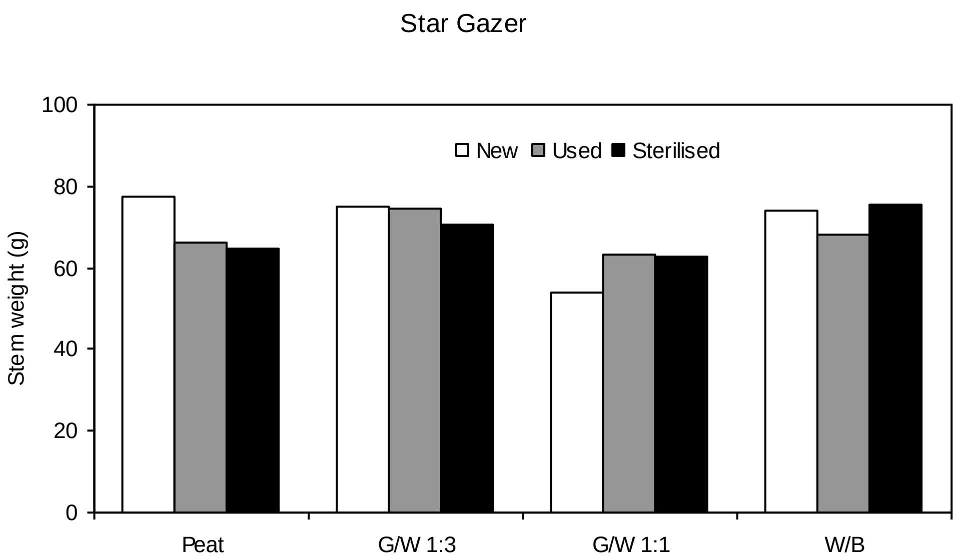
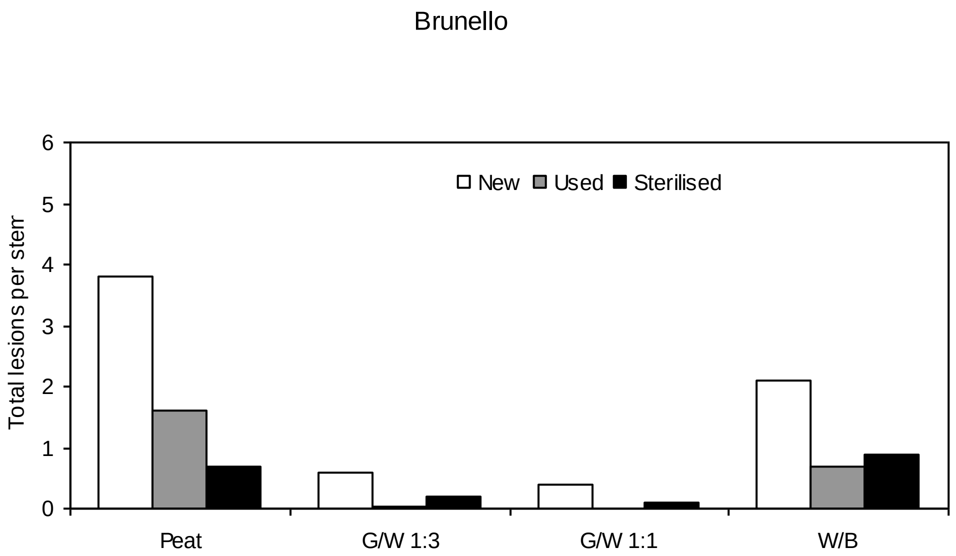
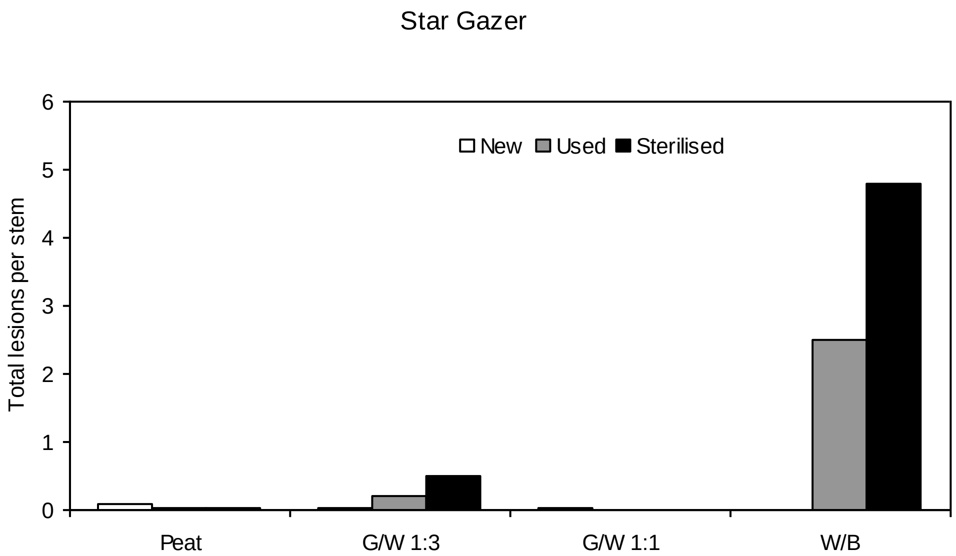


Figure 14. 2002 experiment. Total number of leaf lesions per stem for cvs 'Brunello' and 'Star Gazer' in four substrates either new, used or sterilised used. G/W = green/wood, and W/B = wood/bark, substrates.





Pot-plant performance (2001 experiment)

Marginal means and tables of significance are given in Appendix A (Tables A16-A17), and the main practical results are illustrated in Figures 15-17.

Marketing date
The results (Table A16) showed that, for the dwarf longiflorum cultivar, marketing stage was reached two - three days earlier using the high rate of fertiliser, compared with using the low rate, and using a liquid feed also gave a small advancement, but there were no significant effects due to substrate. 'Butter Pixie' was not responsive to treatments in this respect.

Plant height
'Butter Pixie' plants were taller than the dwarf longiflorum at the marketing stage. Otherwise, the main factor affecting plant height was the substrate, with a significant cultivar x substrate interaction (Figure 15, Table A16). For the longiflorum cultivar, taller plants were produced in peat and wood/bark substrates, and shorter plants in the green/wood substrate (either mixture); for 'Butter Pixie', peat produced the taller plants, and plants were shorter in all three alternative substrates. The longiflorum cultivar responded markedly to fertiliser treatments: the higher rates of base fertiliser reduced stem height, and using a liquid feed increased it. 'Butter Pixie' was unresponsive to fertiliser use, either as base fertiliser or as a liquid feed.

Plant width
Leaf length (or overall plant width) is an important characteristic for a pot-grown lily, and in this respect the dwarf longiflorum plants were wider than those of 'Butter Pixie'. Plant width was affected by all three experimental factors, but principally by the use of liquid feed, and there were several significant interactions between these factors (Figure 16, Table A16). Using a liquid feed increased plant width in both cultivars. Both varieties produced the widest plants when grown in peat, and the narrowest plants when grown in 1:1 green/wood substrate. However, whereas increasing base fertiliser rates progressively increased plant width in the longiflorum variety, plants of 'Butter Pixie' were unresponsive.

Leaf lesions
As with cut-flowers, the presence of leaf lesions was one of the main factors affecting quality in pot-grown lilies. 'Butter Pixie' was largely free of leaf lesions, either of the leaf scorch or *Botrytis* types, while a low number occurred in the dwarf longiflorum cultivar (Figure 17, Table A17). In the dwarflongiflorum, there were more leaf lesions (of either type) in peat-grown plants than in those grown in other substrates, and more where liquid feed was applied.

Basal stem zone
Significant lengths of basal zone were present in the dwarf longiflorum but not 'Butter Pixie'. Treatment effects were almost entirely due to liquid feeding, with prominent basal stem zones in the longiflorum that had received no liquid feed but virtually none where a liquid feed had been used (Table A17).

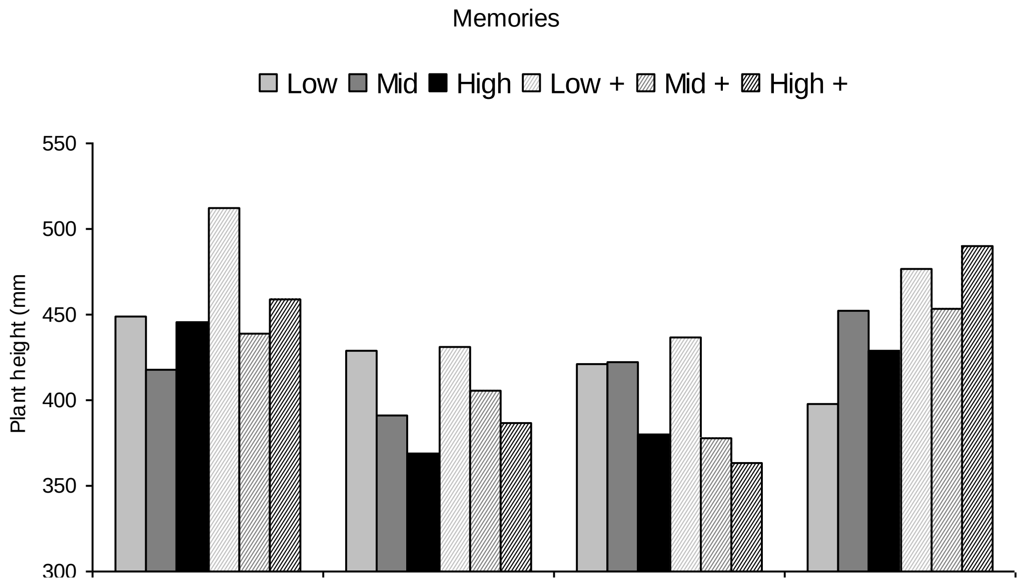
Foliage colour
Pale foliage was much more common in the longiflorum cultivar than in 'Butter Pixie', and in both cultivars – but especially in the longiflorum cultivar – liquid feeding restored normal

foliage colour (Table A17). Overall, 75% of the longiflorum lily plants had pale foliage without liquid feed, but only 3% when a liquid feed was used. For ‘Butter Pixie’, the corresponding figures were 19 and 8%, respectively.

Shelf-life

Records of shelf-life (Table A17) showed that, for the dwarf longiflorum, its duration was affected by substrate and liquid feed. Shelf-life was three to four days longer in peat and in wood/bark substrate than in 1:1 green/wood substrate, and about 1 day shorter using liquid feed than not using it. The shelf-life of ‘Butter Pixie’ was not significantly altered by these treatments.

Figure 15. 2001 pot-plant experiment. Plant height for pot-grown lily cvs dwarf longiflorum and ‘Butter Pixie’ in four substrates with low, medium and high fertiliser rates, with (+ in legend) or without liquid feed.



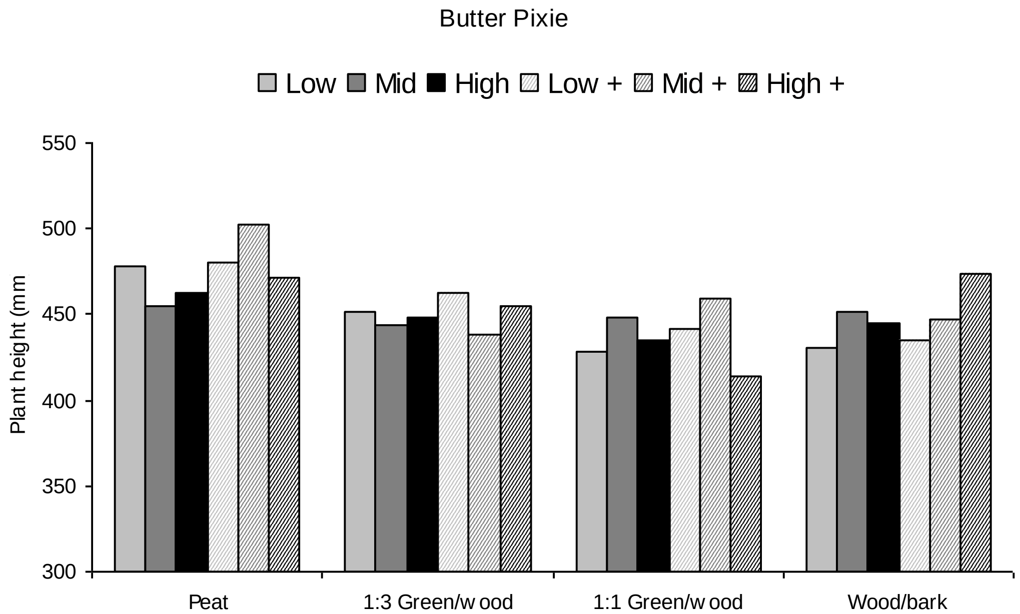
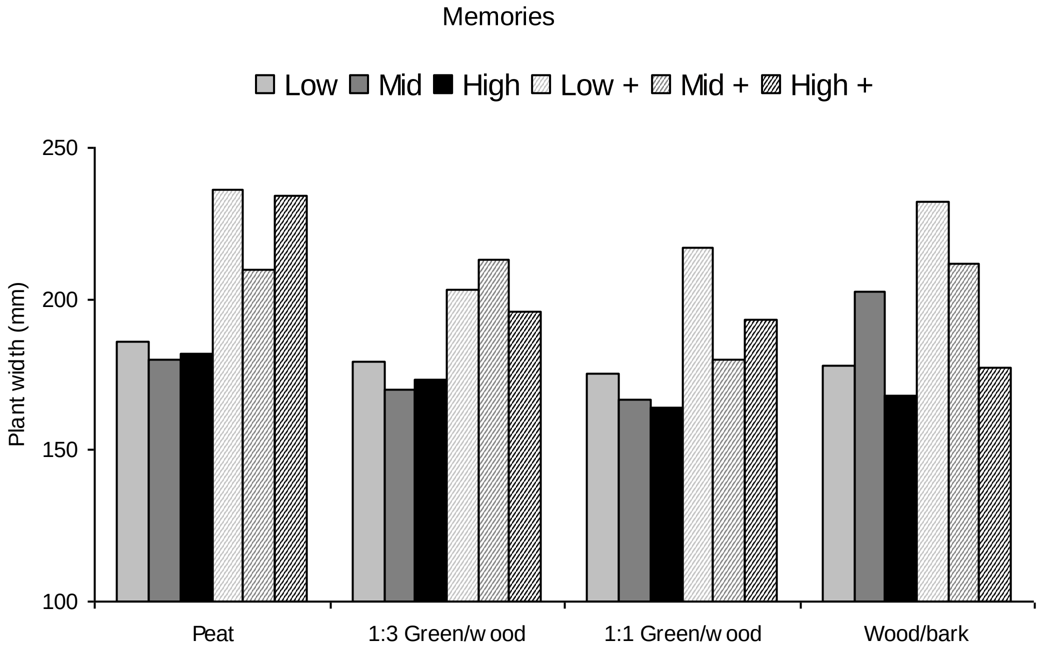


Figure 16. 2001 pot-plant experiment. Plant width for pot-grown lily cvs dwarf longiflorum and 'Butter Pixie' in four substrates with low, medium and high fertiliser rates, with (+ in legend) or without liquid feed.



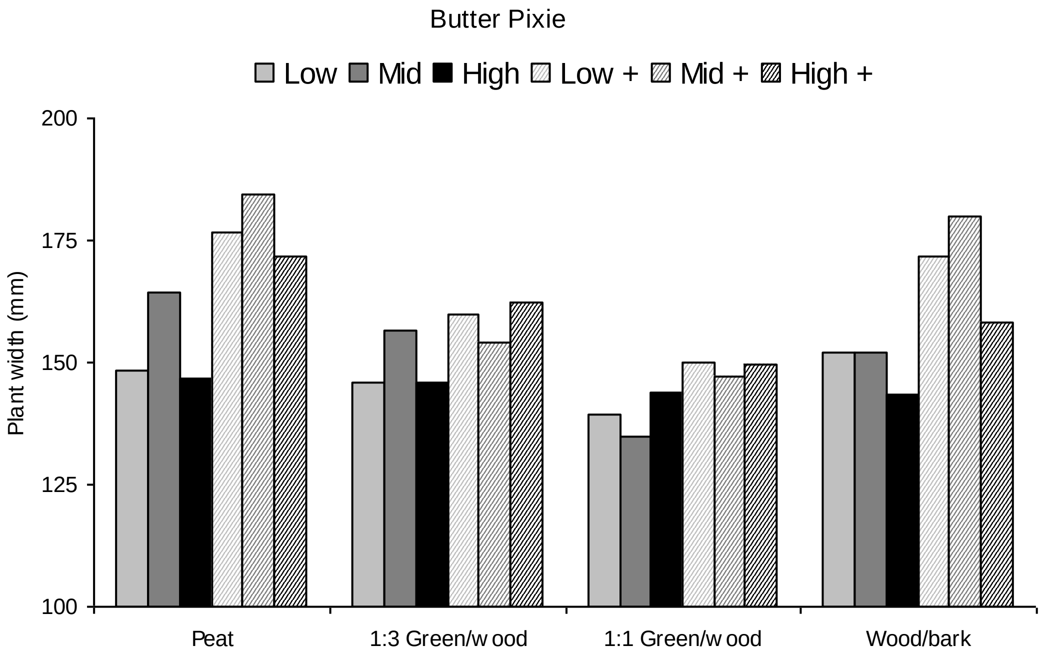
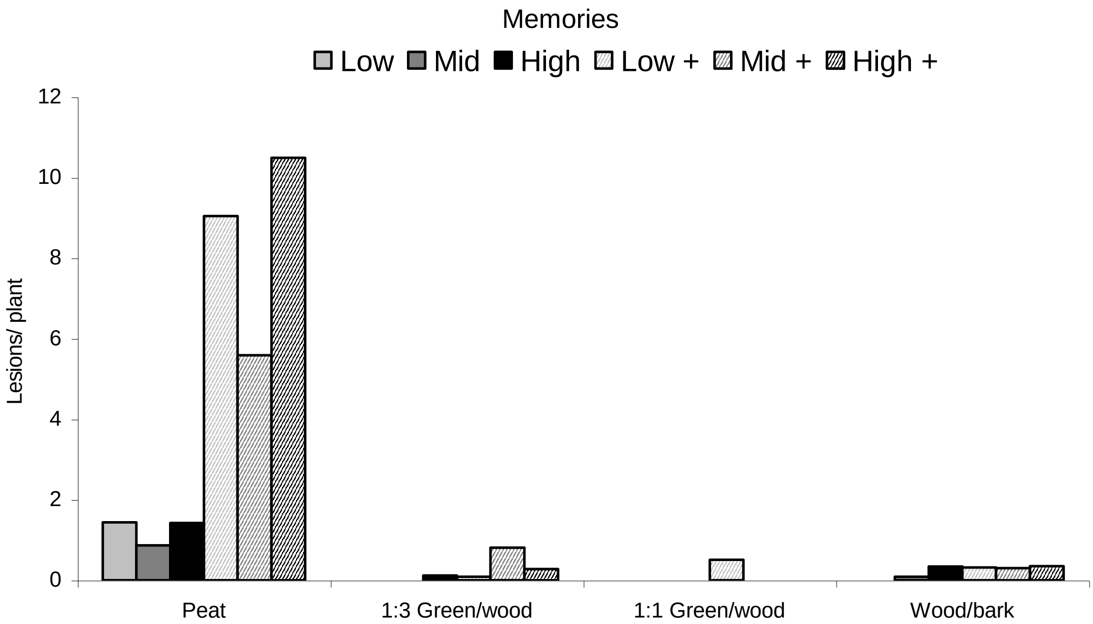


Figure 17. 2001 pot-plant experiment. Total number of leaf lesions per plant for pot-grown lily dwarf longiflorum in four substrates with low, medium and high fertiliser rates, with (+ in legend) or without liquid feed.



RESULTS: ANALYSIS OF SUBSTRATES AND FOLIAGE

General comments on the practical use of substrates

Peat has an attractive dark colour, is light in weight, has good water holding capacity and is relatively 'sterile', but has fine particles. Used peat, in contrast, was heavy, produced weeds, was prone to surface cracking and was not homogeneous due to sand, gravel and plant remains. Both the wood/bark and wood/bark/green substrates were heavy, compacted easily, and had poorer water holding capacity, needing extra watering. The green/coir substrate was fibrous, did not hold water well, and so also needed extra watering.

Substrate and plant analysis, 2000

Each substrate was used with low, medium and high rates of base fertiliser addition. 'Straight' fertilisers were added according to the initial analysis of each test substrate (Tables 1 and 6) to raise the available nutrient levels to those equivalent to the addition of 0.5, 1.0 and 1.5 kg/m^3 of PG-Mix (14:16:18 N:P:K) fertiliser. The main chemical analyses are presented in Figures 18-22, and full tables of analyses are given in Appendix B (Tables B1-B4). In this first year's experiment, chemical analyses were based on conventional, water-extraction methods. It is possible that this extraction method may not be suitable for both peat- and green compost-based materials (see under 'Materials and Methods'), which could lead to the green compost-based substrate having too much fertiliser added. For example, the increases in levels of N and P found later in the growing season in the green/coir-based substrate will certainly have been due to the continued decomposition of this material. This point is discussed later in the 'Results'.

Analysis of substrates at planting
Results are given in Figures 15-16 and Table B1. While there were some minor anomalies in the relative levels of nutrients between low, medium and high rate mixtures, it was accepted that trying to balance nutrient levels precisely in such diverse materials would be somewhat difficult to achieve. Overall, however, the aim of producing a broad range of nutrient levels across all six substrates was achieved.

The density of the wood/bark/green substrate as received, 400g/litre (Table 1), appeared unexpectedly low; the subsequent measurements of 450+ g/litre (Table B1) were considered more realistic.

For all three nutritional regimes, low, medium and high, the pH was around 6.0 for the peat and wood/bark substrates, but higher for the wood/bark/green substrate (pH 7.6) and the green/coir substrate (pH 7.4). For lilies growing in the wood/bark/green substrate, this higher pH did not appear detrimental.

At the low rate of nutrient addition, the electrical conductivity (EC) varied from 146 µS for the new peat to 584 µS for the green/coir substrate, which had a high starting EC. As expected, the high nutrient regime produced higher ECs, ranging from 349 µS for the new peat to 784 µS for the green compost/coir substrate. The conductivity of the green/coir substrate was higher than recommended for lilies for both the medium and high nutrient regimes. However, this material would also have had a higher nutrient buffering activity, and hence a conductivity that would cause root damage in a peat substrate might not do so in a more highly buffered medium.

The high conductivity in the green/coir substrate was due to high levels of potassium and chloride in particular. The wood/bark/green substrate also had higher potassium and chloride levels than the other treatments.

The total water-soluble nitrogen levels at the start of the experiment were between 50 and 121 mg/litre for the low fertiliser regime, 94-160 mg/litre for the medium fertiliser regime, and 174-245 mg/litre for the high nutrient regime. In each case, as expected, the new peat had the lowest nitrogen content. This gave a useful range across the experiment from which to assess the effects of varying nitrogen levels on plant growth and flowering.

Trace element levels are shown in Figure 19. In the three peat substrates, trace element levels were similar, except that iron levels were increased in the recycled peat. Trace element concentrations in the three alternative substrates were higher than in the peat materials, particularly in the case of iron in green compost-containing substrates.

Substrate analysis in mid-experiment

For cv Brunello only, samples were taken from all the substrates during the growing season in June, to check their nutrient status (Table B2). Figure 20 shows the results of substrate analysis for Brunello at planting, at mid-point of the crop, and at cropping. The nutrient levels and conductivity had fallen as expected, due to nutrient uptake by the plants and some leaching of nutrients. The pH values were similar to those at the start of the experiment.

For the low nutrient regime the conductivity ranged from 128 to 297 µS, again the lowest value being for the new peat, but the highest was no longer the green/coir substrate but the used peat. The nitrogen level had fallen to between 16 and 77 mg/litre, the new peat substrate being the lowest and at a level where liquid feeding would have been considered. The green /coir substrate still had high levels of water-soluble potassium and phosphorus, but the chloride level had dropped significantly.

With the medium nutrient regime all the substrates had sufficient nutrient reserves at this mid-way stage, and their conductivity ranged from 145 to 404 µS, with the used peat showing a higher level than the green compost/coir substrate.

At the high nutrient status, the used peat had higher nutrient status than the other substrates, in particular the nitrogen level was significantly higher. This may have been partly due to the higher bulk density of this mix and subsequent reduced amount of leaching of nitrogen, compared with the more free-draining wood-based (wood/bark and wood/bark/green) substrates.

Substrate analysis at the end of the experiment

At the end of the experiment each of the four lily cultivars was sampled separately in each substrate (Table B3). Figure 21 shows the analyses at planting and at cropping for each cultivar. The pH values of the peat treatments and the wood/bark substrate had generally risen, due to the hard irrigation water used, to between 6.0 and 6.5, but this is still an acceptable range for most lily cultivars. The pH of the wood/bark/green and green/coir substrates were still higher at 7.0-7.5, however there were no signs of iron deficiency or other high pH-induced symptoms, and the leaf analysis (see below) showed adequate uptake of manganese despite the high pH. This is again due to nutrient uptake in more highly buffered substrates being less influenced by high pH than it would in a peat with a similar pH resulting from over-liming.

Substrates from trays of all cultivars showed some nitrogen depletion with the low nutrient regime by the end of the experiment. The most vigorous cultivar, Brunello, had depleted the nitrogen level more than the others. For all cultivars the analysis showed low available nitrogen levels in the two wood-based substrates, even with the high nutrient level, probably due to greater leaching and some immobilisation of nitrogen as the wood and bark continued to break down.

Leaf analysis at cropping
Figure 22 (and Table B4) present the results of foliage analysis for the five cultivars at cropping. Leaf nitrogen levels did not vary significantly between treatments, and were all in the 'satisfactory' range, although the two wood-based substrates seemed to show more response to increasing base fertiliser level than the peat or green/coir substrates.

The potassium levels in the lily leaves appeared to be higher in the green/coir substrate, not surprising as it had a much higher potassium status than the other materials. This may have been hindering uptake of magnesium (this occurs if there is high ratio of potassium to magnesium), as the leaf magnesium levels were slightly low in this treatment.

Manganese levels in the leaves were higher for the wood/bark/green substrate than the other treatments, however, symptoms of manganese toxicity were not evident on the plants.

Figure 18. 2000 experiment. Pre-planting analysis of six substrates (each with low, medium and high rates of fertiliser added): pH, conductivity and major nutrient concentrations determined by water extraction. Note that the vertical axis of several graphs has been considerably expanded to take in high nutrient levels in peat and green/coir substrates. (Substrates: peat = new peat; mix = 50:50 new and used peat; used = used pear; W/B = wood/bark; W/B/G = wood/bark/green; G/C = green/coir).

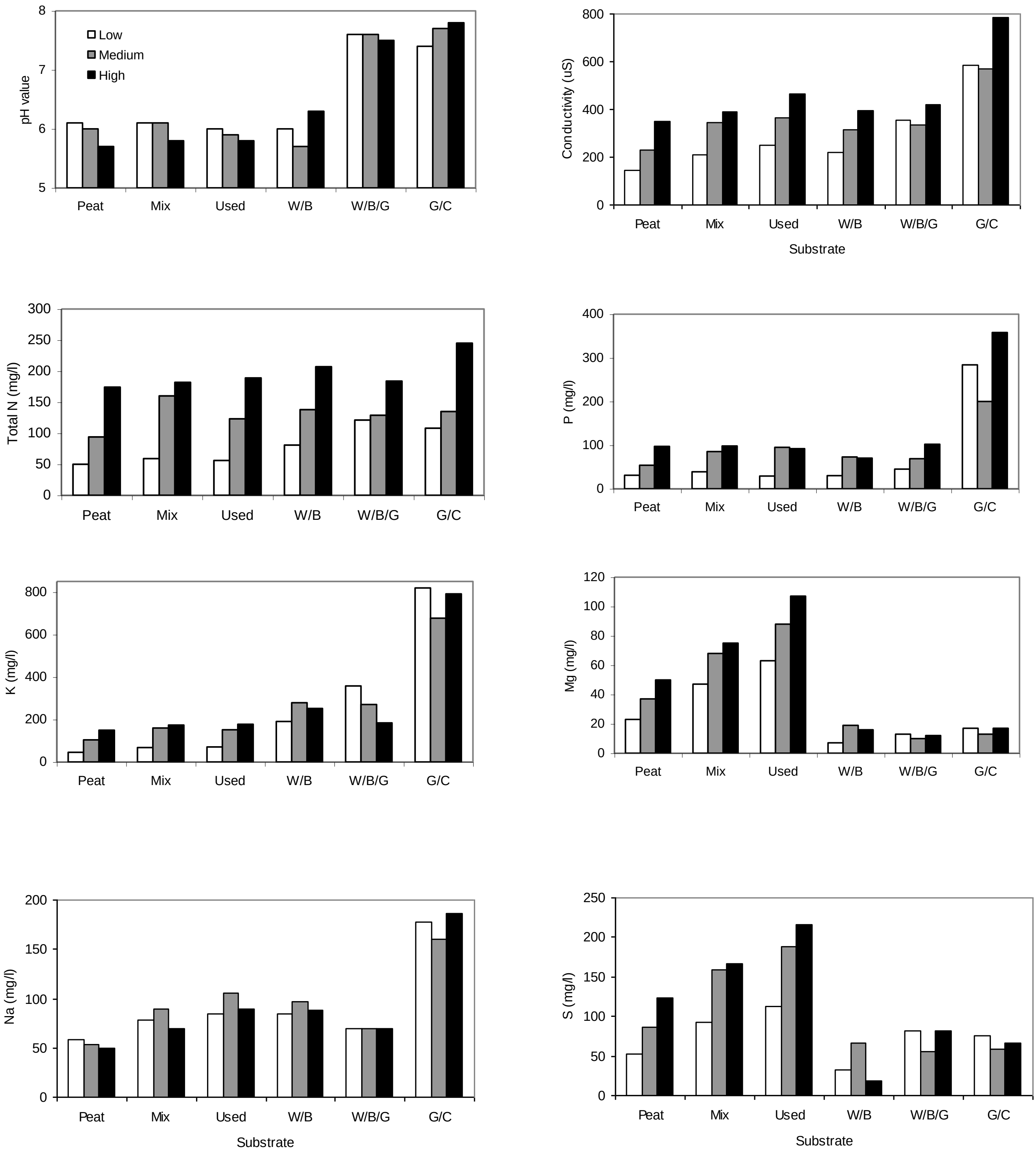


Figure 19. 2000 experiment. Pre-planting analysis of six substrates with medium rate of fertiliser: **trace elements** determined by water extraction. Note logrithmic vertical axis. (Substrates: peat = new peat; mix = 50:50 new and used peat; used = used pear; W/B = wood/bark; W/B/G = wood/bark/green; G/C = green/coir).

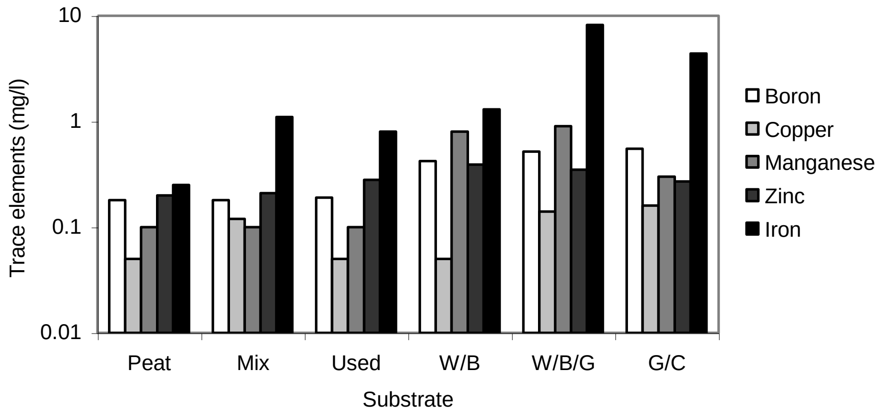


Figure 20. 2000 experiment. Analysis pre-planting, mid-way, and at cropping of six substrates with medium rate of fertiliser added, cv Brunello: pH, conductivity and major nutrient concentrations determined by water extraction. (Substrates: peat = new peat; mix = 50:50 new and used peat; used = used pear; W/B = wood/bark; W/B/G = wood/bark/green; G/C = green/coir).

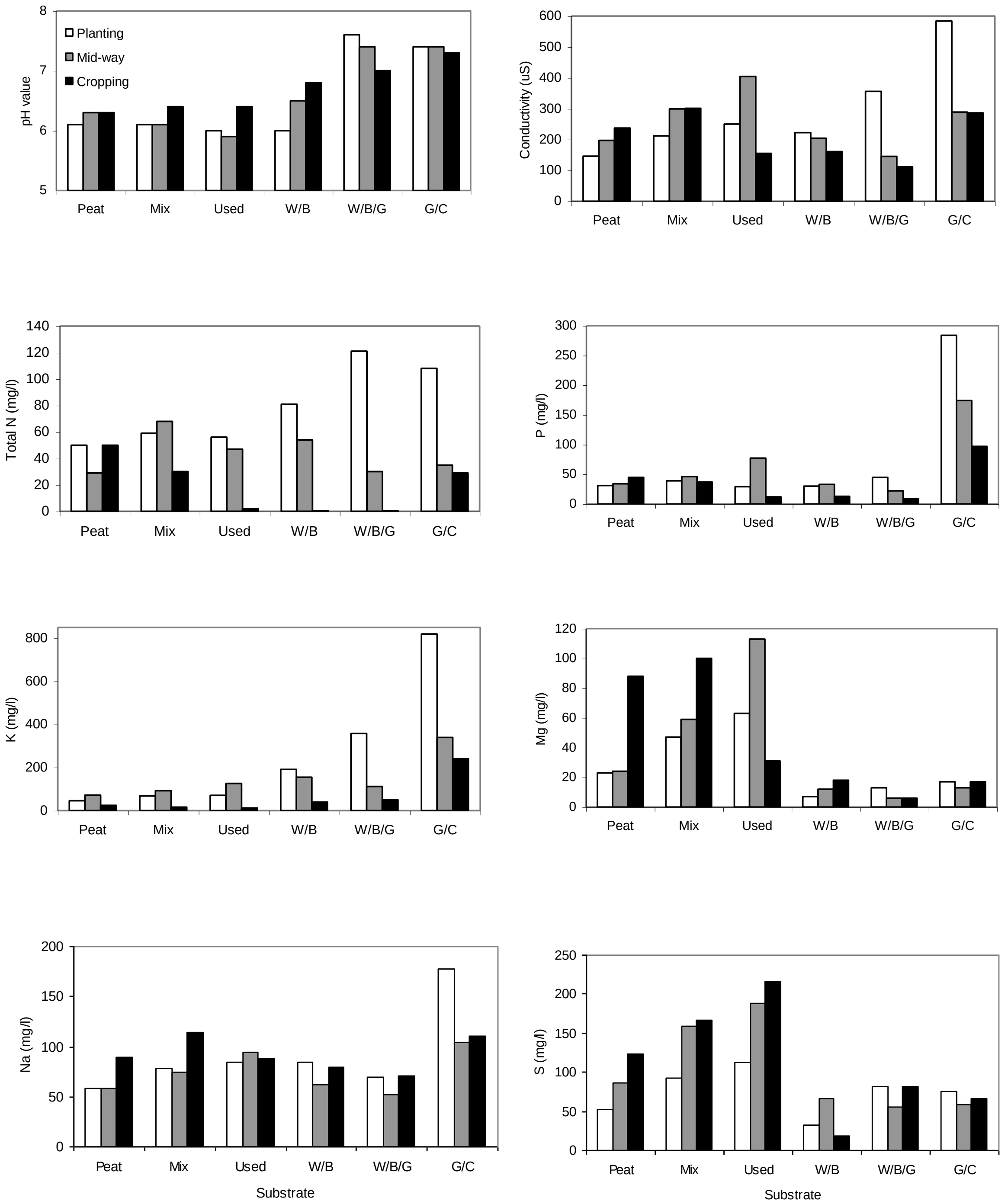


Figure 21. 2000 experiment. Analysis pre-planting and at cropping of six substrates with medium rate of fertiliser added, for five cultivars: pH, conductivity and major nutrient concentrations determined by water extraction. (Substrates: peat = new peat; mix = 50:50 new and used peat; used = used pear; W/B = wood/bark; W/B/G = wood/bark/green; G/C = green/coir).

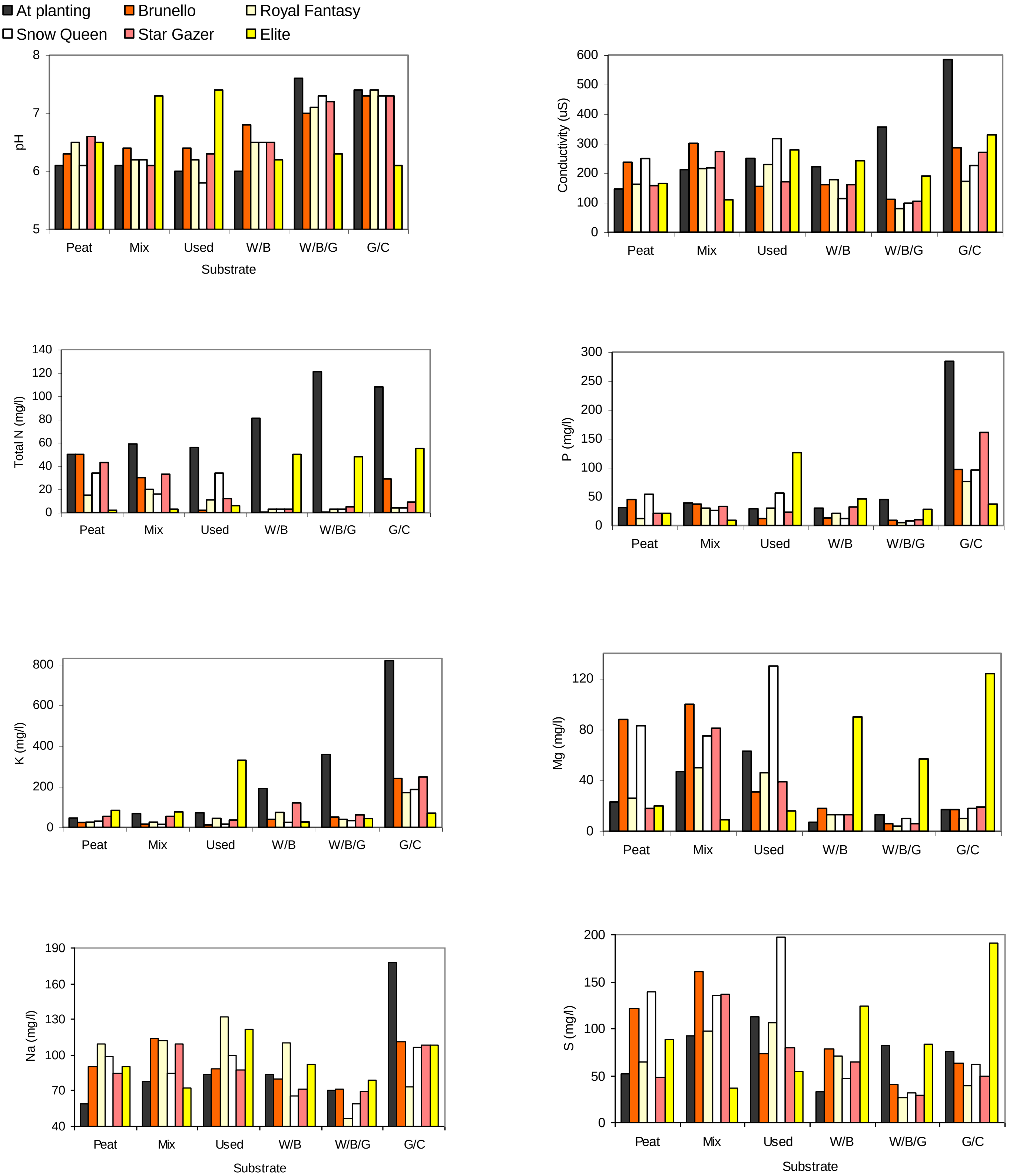
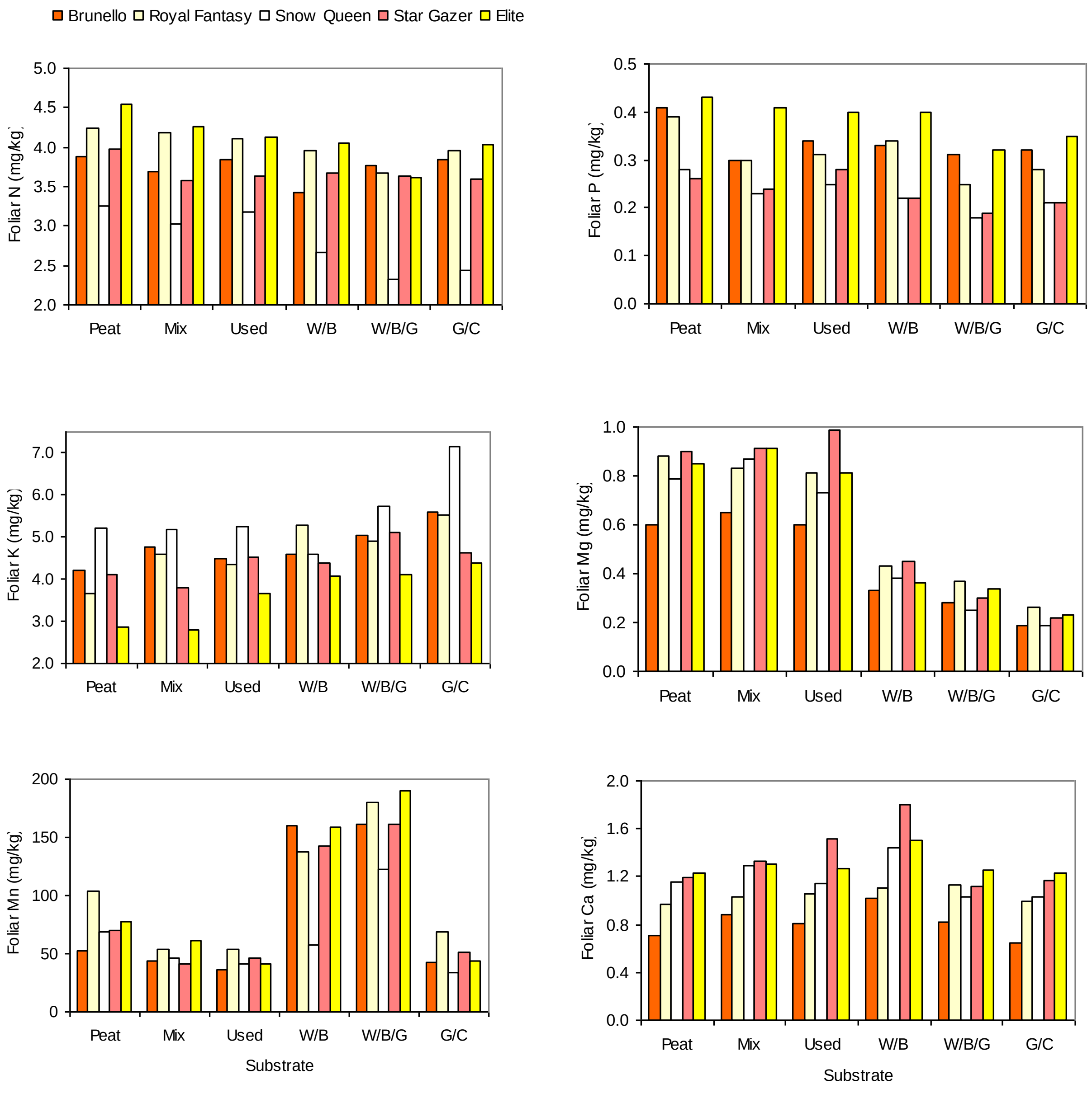


Figure 22. 2000 experiment. Analysis of foliar nutrients at cropping of five cultivars in six substrates with medium rate of fertiliser. (Substrates: peat = new peat; mix = 50:50 new and used peat; used = used pear; W/B = wood/bark; W/B/G = wood/bark/green; G/C = green/coir).



Substrate and plant analysis, 2001

Each of the four selected substrates was amended with low, medium and high rates of base fertiliser, these being reduced from the levels used in 2000 to 0.25, 0.75 and 1.25 kg/m^3 of PG-Mix equivalents (Tables 2, 3 and 7). The main results are shown in Figures 23-26, and full results are in Appendix B (Tables B5-B9). These results cover the analysis for both the main and pot-plant experiments.

Analysis of substrates at planting
Results are given in Figure 23 and Table B5. For all fertiliser rates of peat and wood/bark substrates the pH was between 5.9 and 6.3. By adding 25% or 50% of green compost to the wood-based substrate, the pH was increased to about 7.0 and 7.7, respectively.

At low rates of fertiliser addition, the EC of substrates ranged from 95 µS for peat to 208-219 µS for the other substrates. The high nutrient regime gave ECs of 246 µS for peat and 265 µS for wood/bark; in the green compost/wood substrate the EC was higher at 394 and 426 µS for the two mixes. However, all these levels were within ADAS Index 1, except for the medium and high nutrient rates with 1:3 green compost/wood substrate. For substrates with high proportions of wood-based material (wood/bark and 1:3 green/wood), the high EC values were due to high levels of K and NO_3 and, for those rich in green compost, Cl.

Substrate density for peat was 215-275 g/litre. Other substrates were more dense, 351-362 for wood/bark substrate and 394-479 g/litre for green compost/wood mixes, in line with the previous year's findings.

The total N for low fertiliser regimes was low at 3-21 mg/litre, except for wood/bark substrate where it reached 115 mg/litre. For the medium fertiliser regime, the EC values were 9 mg/litre for 1:1 green/wood, 60 mg/litre for peat, and 160 or 212 for the two wood-based substrates. For the high fertiliser regime, the EC values were 50 mg/litre for 1:1 green/wood, 109 mg/litre for peat, and 168 or 258 for the two wood-based substrates.

Levels of the trace elements B, Mn, Zn and Fe were generally higher in non-peat substrates than in others (Figure 24).

Substrate analysis at the end of the experiment
Results are shown in Figure 25 and Appendix Table B7. The most obvious result was that nitrogen levels were very depleted where no liquid feed had been used, irrespective of cultivar. Higher N levels were maintained using liquid feed with peat and, to a lesser extent, wood/bark mix. Other nutrients – P, K and Mg - while not being entirely depleted, remained at higher concentrations in peat where a liquid feed had been used.

Leaf analysis
Samples of pale and normal green leaves were analysed at cropping (Figure 26, Table B9). Normal green leaves had higher levels of Ca, Mg, P and, especially, Mn. There were no consistent differences between pale and normal leaves in concentrations of N or K.

Figure 23. 2001 experiment. Pre-planting analysis of four substrates (each with low, medium and high rates of fertiliser added): pH, conductivity and concentrations of major nutrients determined by water extraction (left) and $CaCl_2$/DTPA extraction (right).
(Continued on next page)

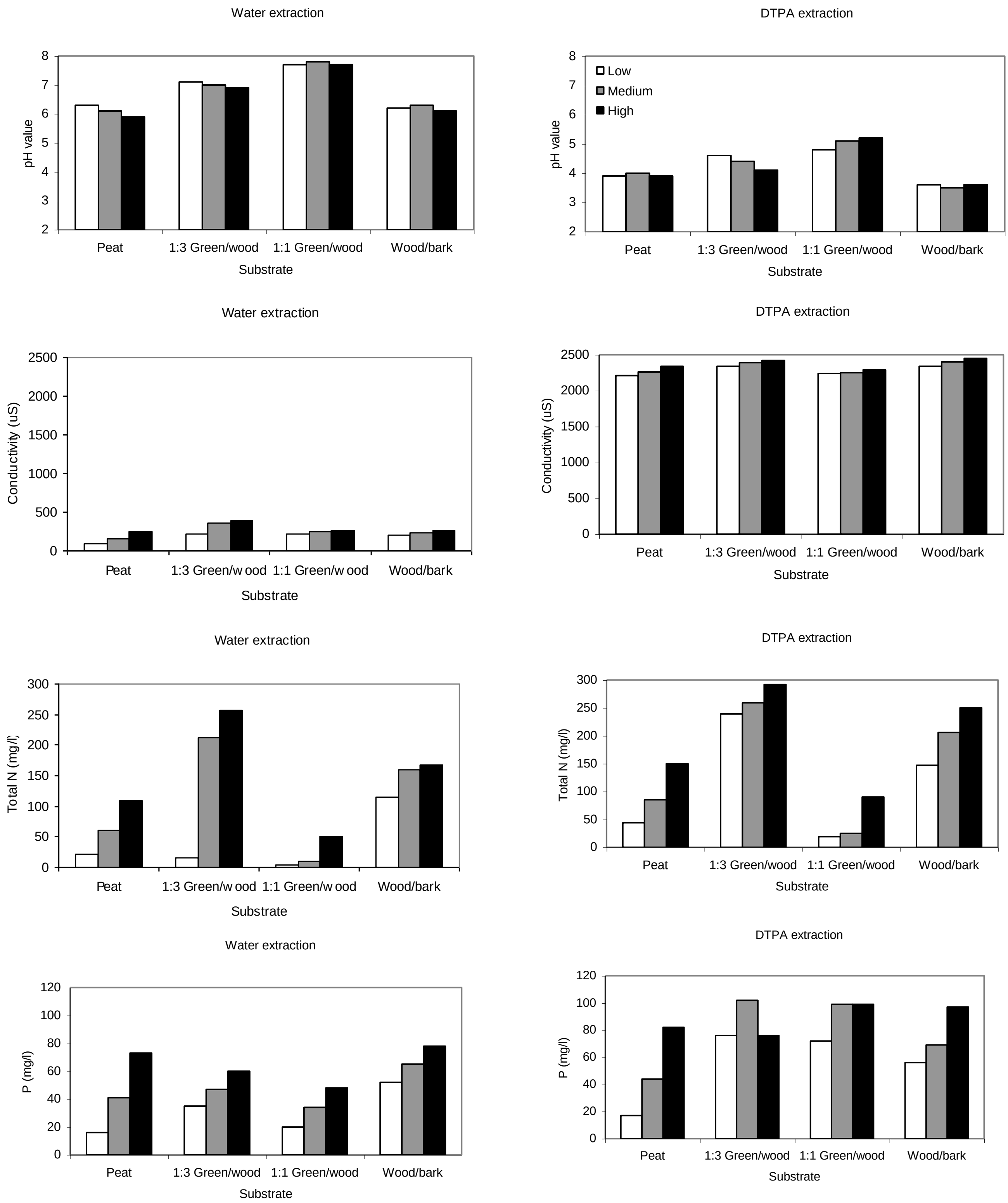


Figure 23 (continued).

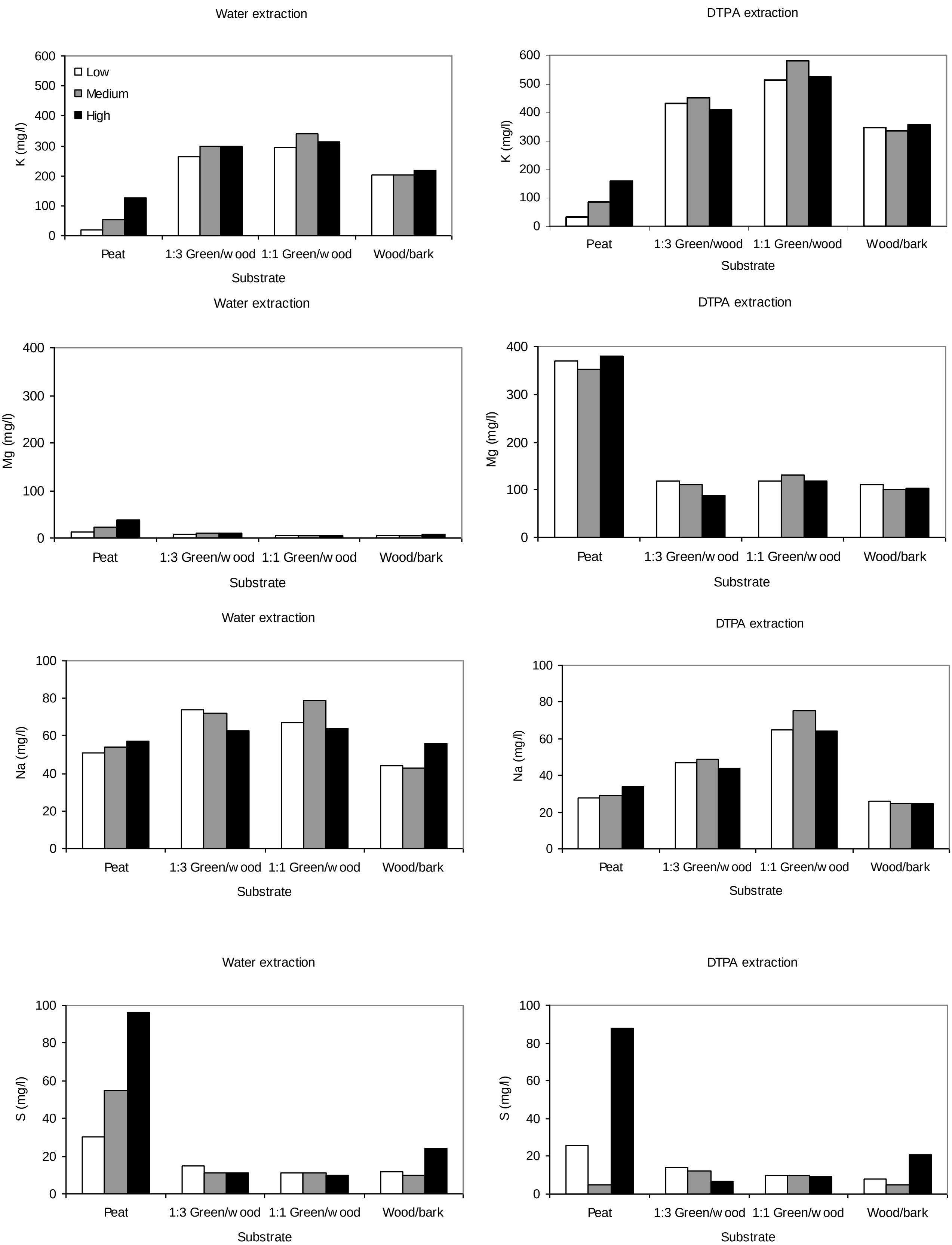


Figure 24. 2001 experiment. Pre-planting analysis of four substrates (with medium rate of fertiliser added): concentrations of **trace elements** determined by water extraction (left) and DTPA extraction (right). Note logrithmic vertical axes.

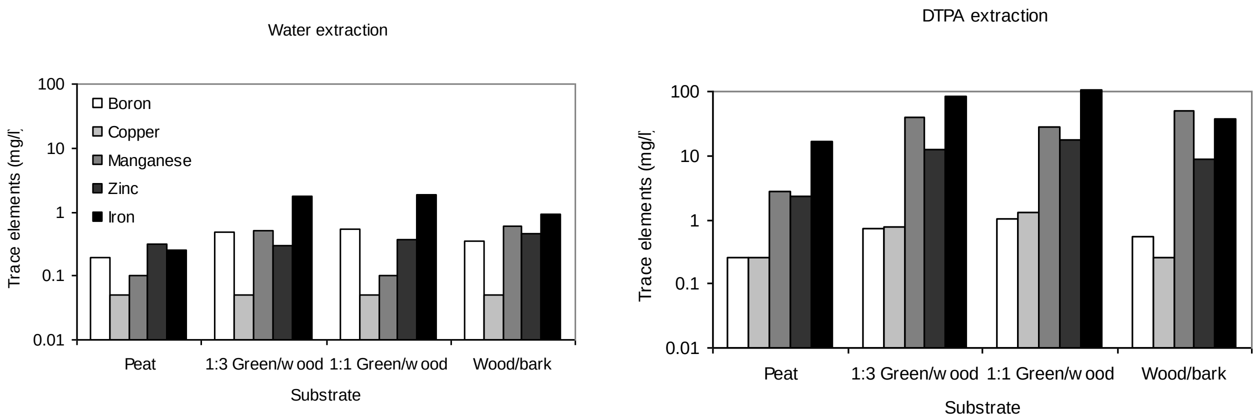


Figure 25. 2001 experiment. Analysis pre-planting and at cropping of four substrates with medium rate of fertiliser added, for six cultivars, determined by water extraction. Treatments with no liquid feed on left, and with liquid feed on right.

(Continued on next page)

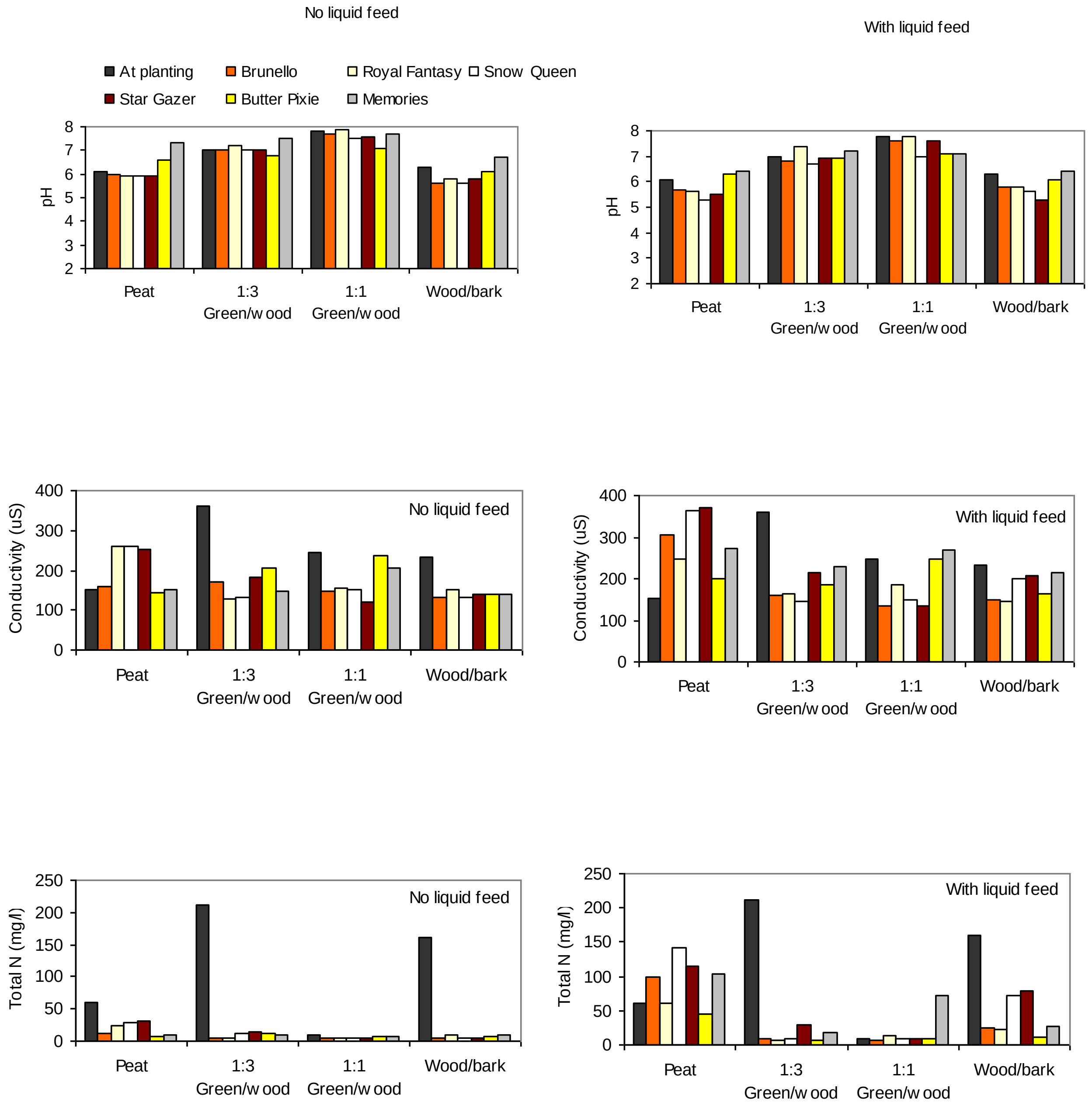


Figure 25 (continued).

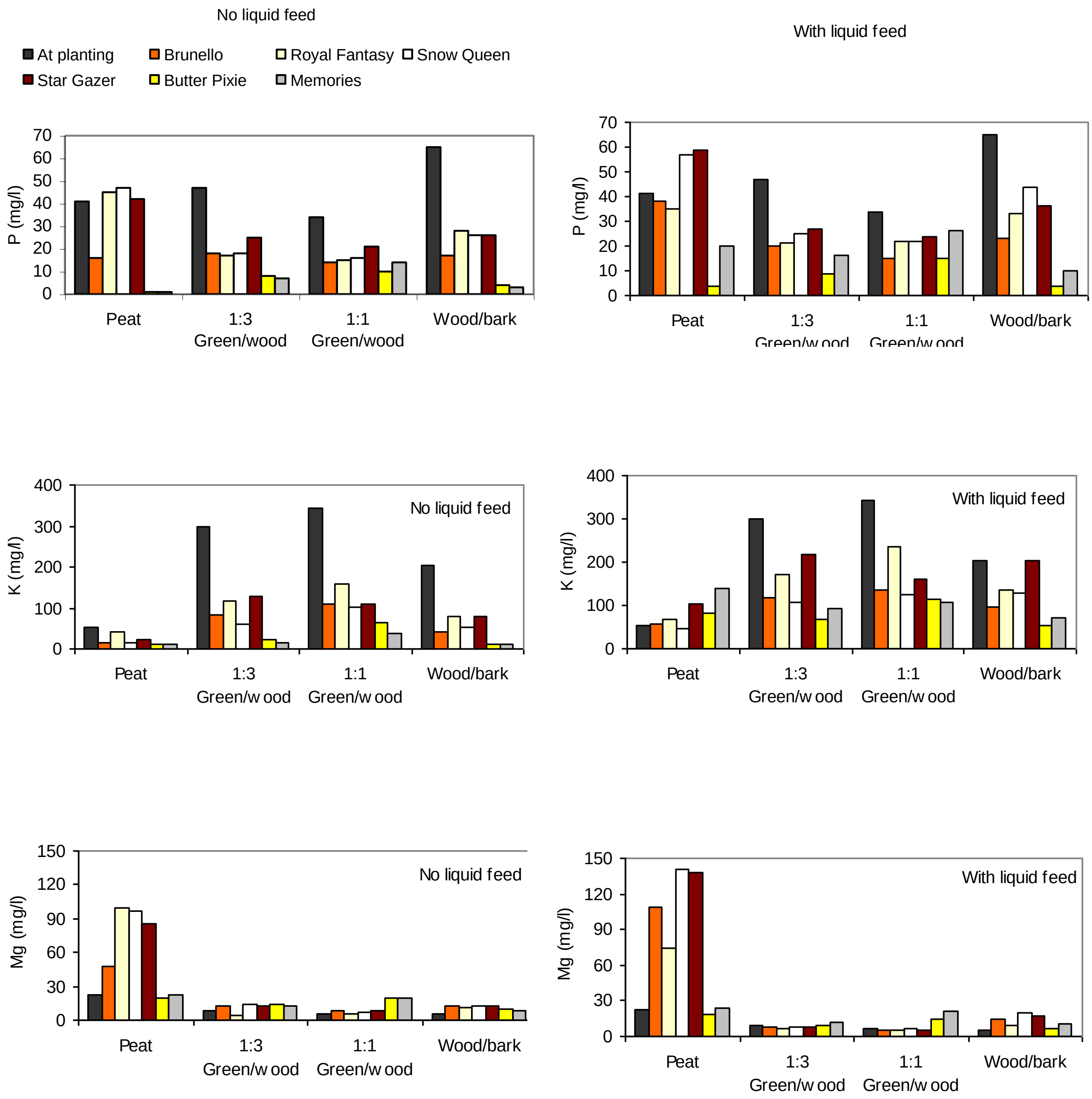
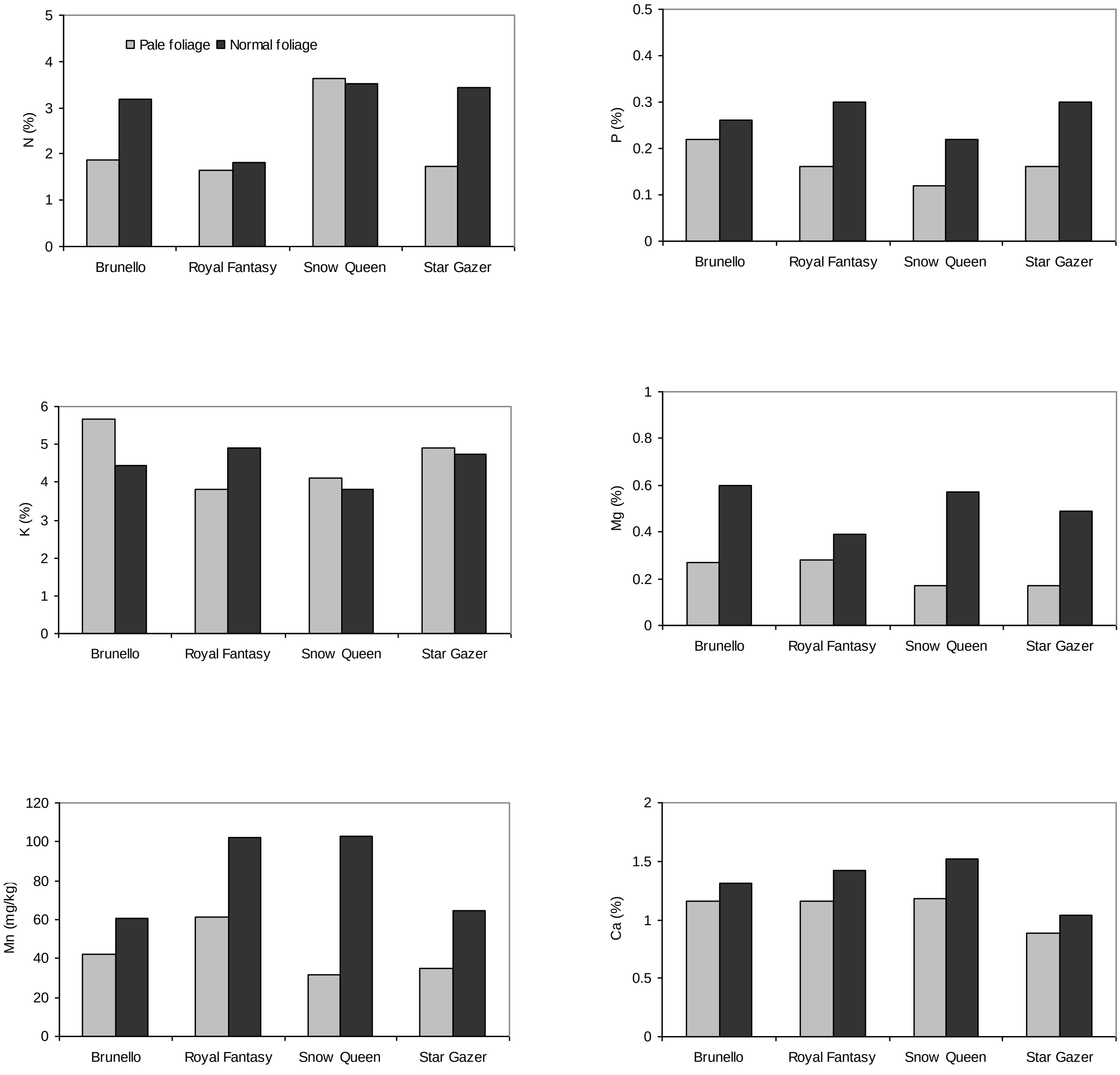


Figure 26. 2001 experiment. Analysis of foliar nutrients in pale and normal green foliage of four cultivars at cropping.



Substrate and plant analysis, 2002

Each of the four selected substrates, amended with a medium rate of base fertiliser (Tables 4, 5 and 8), was used ‘as new’, as the used material, and as used material which had been sterilised. The main results are shown in Figures 27-28, and full results are in Appendix Tables B10-B14.

Analysis of substrates at planting and at the end of the experiment

Figure 27 (and Tables B10 and B12) show the analyses of substrates at planting and at the end of cropping, determined using water extraction. The new 1:1 green/wood substrate showed a very high level of potassium at the start of the experiment, while re-cycled peat had very high levels of magnesium. There were fairly uniform increases in pH, decreases in conductivity, and depletion of major nutrient levels (especially nitrogen) over the growing season.

Leaf analysis

Nutrients in pale and normal green leaves of Star Gazer at cropping are given in Table B14. The levels of N, Mg and Mn were markedly greater in normal foliage.

Figure 27. 2002 experiment. Analysis pre-planting and at cropping of three substrates either new (N), used (U) or used and sterilised (S), determined by water extraction.
(Continued on next page)

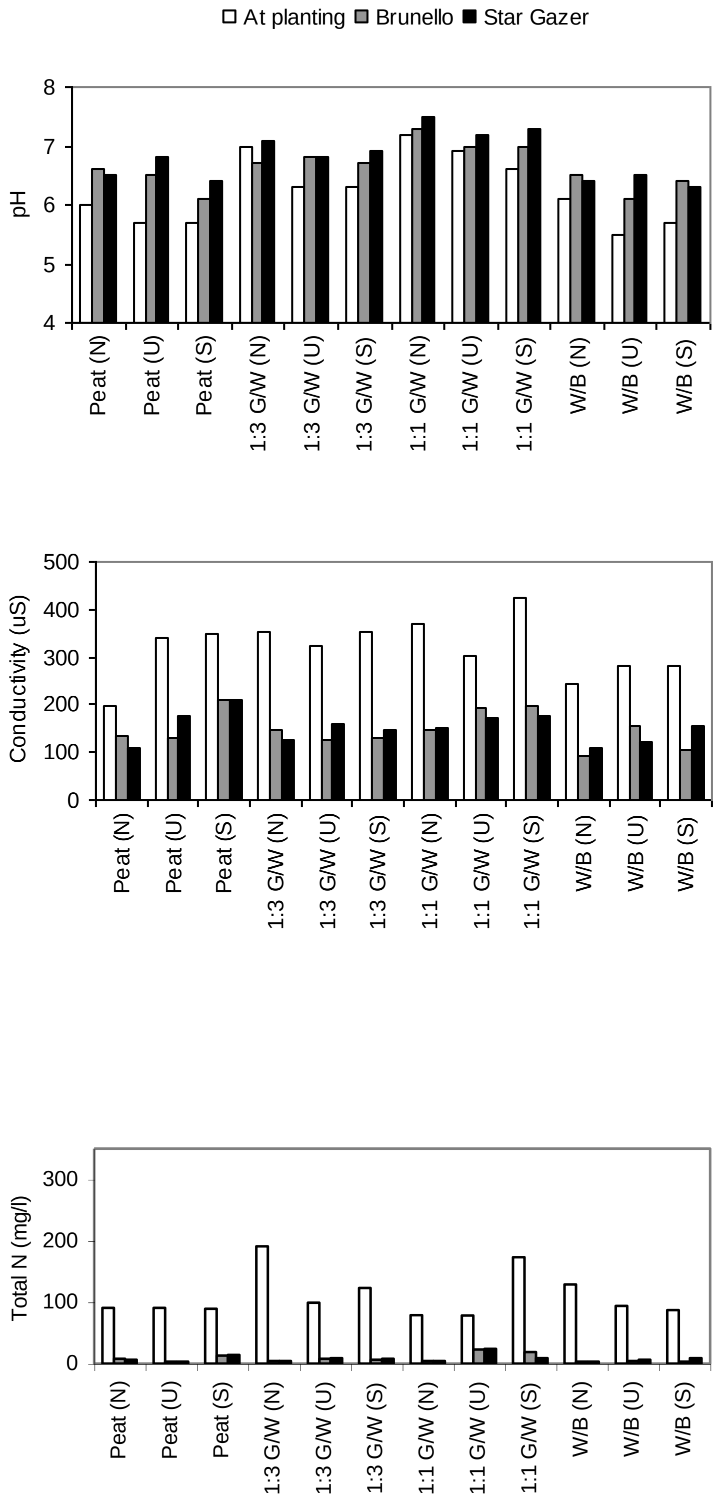


Figure 27 (continued).

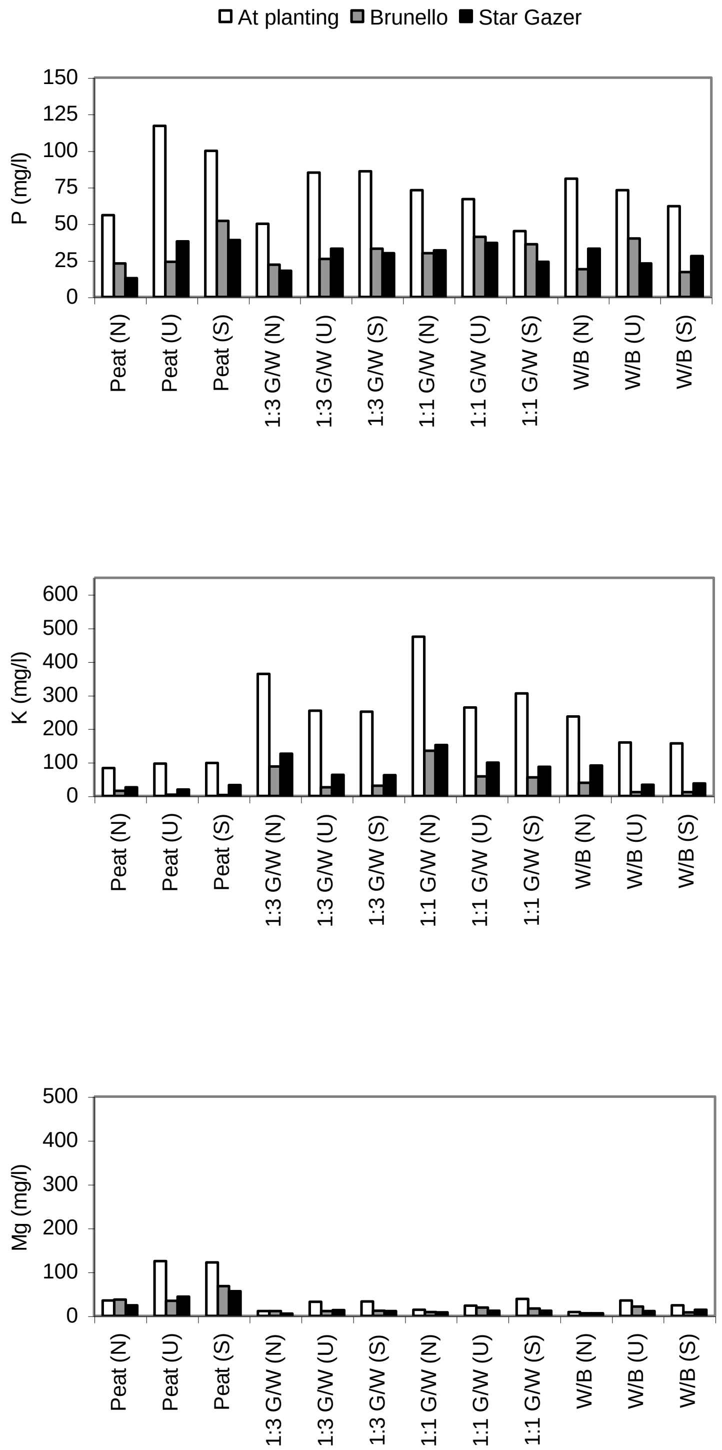
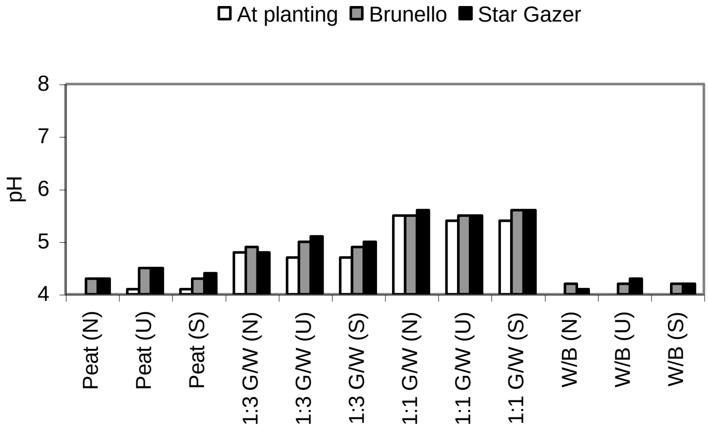
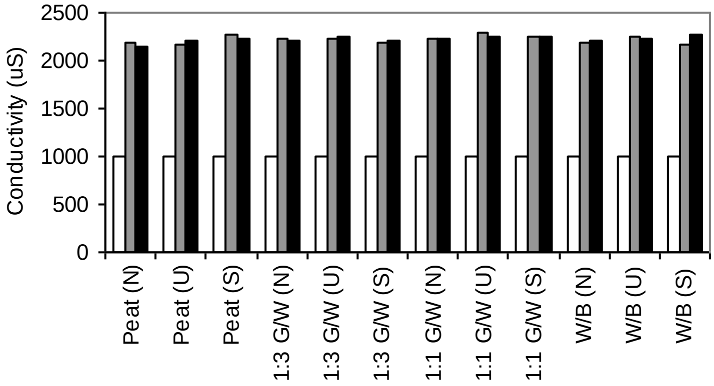


Figure 28. 2002 experiment. Analysis pre-planting and at cropping of three substrates either new (N), used (U) or used and sterilised (S), determined by DTPA/$CaCl_2$ extraction. Note difference in vertical scale for total N, compared with Figure 27.

(Continued on next page)





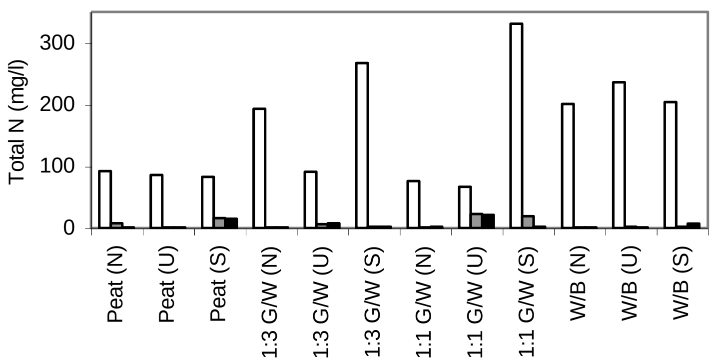
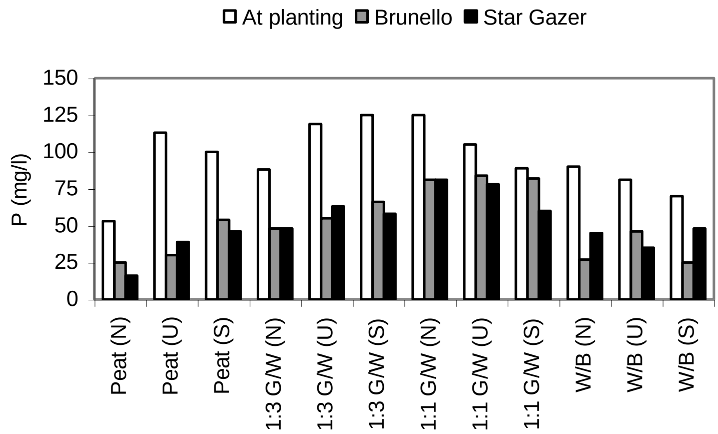
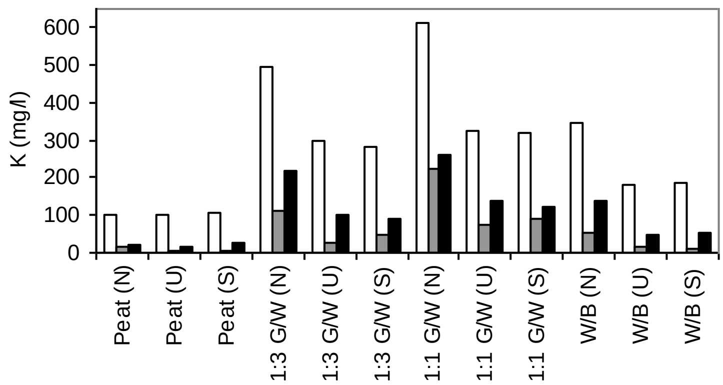
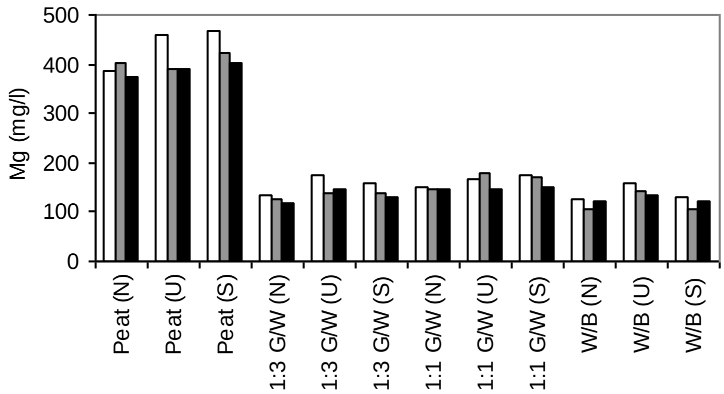


Figure 28 (continued).







Comparison of water and DTPA/$CaCl_2$ methods

For the main 2001 experiment, substrate analyses using water and DTPA/calcium chloride extraction are given in Figures 23 - 25 (Tables B5-B8). The main differences between the two methods are listed below. Compared with water extraction, DTPA/calcium chloride extraction gave:

- As expected, lower pH values and high conductivities
- Slightly higher total N concentrations
- Somewhat higher P and K levels in green/wood-based substrates (slightly higher in wood/bark substrate)
- Higher Mg levels, and much more so in peat substrate
- Generally lower Na levels
- Similar S and B levels
- Higher Cu, Mn, Zn and Fe levels in all substrates

For the 2002 experiment, substrate analyses using water and DTPA/calcium chloride extraction are given in Figures 27 - 28 (Tables B10-B13). Compared with water extraction, DTPA/calcium chloride extraction gave:

- As expected, lower pH values and high conductivities
- Somewhat higher N, P and K concentrations for the three alternative substrates
- Substantially higher Mg levels, much more so in peat substrate

While the DTPA/calcium chloride method does give higher concentrations for N, P and K and, especially for the trace elements, in the alternative substrates, this merely posed the question of what alternative target nutrient levels should be aimed for. As the conductivity using DTPA/calcium chloride is on the 'soil analysis' scale, it appears high, but values of 2210 to 2400 µS represent only an ADAS Index of 1. There does not seem to be an accepted interpretation guide for the DTPA/calcium chloride method.

DISCUSSION

Box-grown cut-flowers

This project was based on experiments conducted over three years, and has given some consistent messages on the suitability of alternative substrates and recycled materials as growing media for glasshouse lilies. Five important lily cultivars – Brunello, Élite, Royal Fantasy, Snow Queen and Star Gazer - were box-grown in peat and in proprietary substrates based on wood, bark, green compost and coir, referred to here for convenience as wood/bark, wood/bark/green, green/coir and green/wood substrates. The main findings can be summed up as follows:

- *Cropping dates and length of cropping period*

  There were some significant effects of substrates and fertilisers on the date and period of flower cropping, but these were small and commercially insignificant – often less than 1 day.
- *Flower yield*

  Flower yield was unaffected by substrate and fertiliser treatments.
- *Stem length*

  The longest stems were consistently obtained using wood/bark and wood/bark/green substrates. Substrates based on green compost gave short plants, sometimes particularly affecting the extension of the inflorescence. Peat substrates gave intermediate results. Base fertiliser added at the highest rate (equivalent to using 1.5 kg/m3 PG-Mix) sometimes resulted in shorter stems, and low rates tended to give longer stems. Using a liquid feed, combined with a low rate of base fertiliser, enhanced stem length. Cultivars varied in the extent to which they responded to treatments by altered stem lengths: for example, Brunello was relatively unresponsive.
- *Stem weight*

  Wood/bark substrates also produced the heaviest and densest stems, while those from plants grown in green substrates were the lightest. Peat substrates generally produced stems of intermediate or low weight. Medium rates of base fertiliser, and using a liquid feed, also produced heavier stems.
- *Length of basal zone*

  The premature loss of basal leaves is a quality problem in some lily cultivars, and here it was notable in cultivars Brunello and Snow Queen, although it was much shorter in the latter. Growing in wood/bark, wood/bark/green and new peat substrates gave Brunello plants with short basal zones, while the basal zone was long using new (but not recycled) green compost substrates. Liquid feed treatments reduced the length of the basal zone. In Snow Queen, the basal zone was shortest in peat and where a high rate of base fertiliser was used.
- *Floret numbers*

  The highest numbers of viable florets (and conversely the lowest numbers of abscised or aborted florets) occurred in wood/bark substrate, and the lowest using substrates based on green compost (green/coir and 1:1 green/wood substrates). Increasing base fertiliser levels or using a liquid feed resulted in more viable florets.
- *Foliage colour*

  In this project Snow Queen was the cultivar most affected by pale foliage. Growing in peat, or in any substrate with a high rate of base fertiliser, produced Snow Queen plants with darker foliage, while using alternative substrates with a low rate of fertiliser produced pale foliage. As mentioned for the length of the basal zone, in the case of green compost substrate this disadvantage applied only to the new material, once recycled the results were satisfactory. Higher rates of base fertiliser, and using a liquid feed, gave darker foliage.

- *Leaf lesions*

  Lesions encountered include leaf scorch, *Botrytis*-like and other lesions. The numbers of leaf lesions varied with treatment in Brunello, Élite and Royal Fantasy, where they occurred mostly in plants grown in new peat with a high fertiliser rate, with many fewer lesions in wood/bark, wood/bark/green, 1:1 green/wood and recycled peat substrates. In the leaf scorch-prone cultivar Élite there were very few lesions in the wood/bark substrate, in comparison with other substrates. New substrates produced more lesions than recycled materials. Increasing base fertiliser levels or using liquid feed resulted in more lesions. There were also leaf lesions in Snow Queen, but their numbers did not vary with treatment. Leaf lesions were rare in Star Gazer.
- *Root growth*

  Root growth was more extensive in wood/bark and new peat substrates, than in the other substrates.
- *Vase-life*

  Vase-life was unaffected by substrate and fertiliser treatments.

Pot-plants

Similar trials were carried out using two pot-grown dwarf lilies, cv Butter Pixie and a new longiflorum cultivar. These varieties were quite different in their characteristics. Butter Pixie was shorter in alternative substrates than in peat, an advantage for a pot-plant, and was unresponsive to fertiliser levels regarding plant height and width, and was not prone to leaf lesions, a basal zone or pale foliage. The dwarf longiflorum cultivar was shorter in green/wood substrate than in peat or wood/bark substrates. It was shorter and wider using high fertiliser rates, had more leaf lesions in peat than in alternative materials; a liquid feed reduced lesion numbers and basal zone length and improved foliage colour. Substrate and fertiliser treatments did not significantly affect the time in the glasshouse to reach marketing stage. In the dwarf longiflorum cultivar growing wood/bark substrates, the shelf-life was slightly longer than in some other materials, a useful finding as there are sometimes concerns in the industry about shelf-life in peat alternatives.

General discussion

In spite of the wide range of substrates and fertiliser levels tested in the experimental work reported here, it was striking that good or acceptable blooms were obtained from most bulbs in many of the treatment combinations. Several attributes – the total yield of blooms, cropping dates and vase- or shelf-life – were, for all practical purposes, unaffected by either substrate or fertiliser usage. Plant quality aspects, however - such as stem length and weight, number of florets and freedom from defects (such as leaf scorch and a basal stem zone) – were highly dependent on the substrate and fertiliser regime used. In many instances the highest quality blooms were obtained using the wood/bark and wood/bark/green substrates, those from the green/coir substrate used in the first year of the project were not as good. The wood-based materials yielded the longest and heaviest stems, shortest lengths of basal zone, fewest leaf lesions, most viable florets and better root development. Results from the three peat substrates were generally intermediate, although the relative performance of new, used and mixed new and used peat varied according to the attribute being measured. For example, plants in recycled peat performed well in terms of stem length and freedom from leaf lesions. In contrast, those in new peat gave plants with good root development and short lengths of stem bearing yellowing leaves, but, particularly when a high rate of fertiliser had been added, had more leaf lesions. The differences between the new and used peat would be partly due to changing properties as the peat degraded (increasing biological activity and buffering capacity) and partly to the various materials or contaminants added (sand, fertilisers and plant debris).

In this project the relative performance of lilies in the peat substrates was notably poorer than in the two wood-based substrates. This gave a very positive message: high-quality lilies can be produced in alternative substrates. It should be noted that the results obtained for the non-peat substrates used in this project should not be extrapolated as general comments on these types of materials, and certainly not to imply that any or all of the substrates was being used optimally, as optimal use would develop with experience and practice. The alternative materials used were considered likely to have wide availability and good consistency, and all could be modified for particular requirements. The formulation of the green/coir substrate used produced lilies that were relatively poor in some respects, and part of the reason for this could be that nutrients in these materials may have been underestimated by the analysis methods employed (see below). Green composts, even when well composted, will continue to degrade in use, leading to the build-up of excessively high levels of nutrients which cannot easily be predicted. Green compost-based substrates offer a number of advantages over other materials, including being truly recycled and sustainable. In the second year of the project, therefore, mixtures of green compost- and wood-based materials were tested, at ratios of 1:1 and 1:3, attempting to combine the attractive features of each, and good results were obtained with 25% green compost. The alternative materials tended to be less water-retentive than peat, requiring some additional labour inputs or changes to irrigation regimes. The wood-based materials were somewhat heavier than peat, a disadvantage only where manual labour is being relied upon. All three alternatives were pleasant to handle, of attractive appearance, free of weed seeds, and provided good root anchorage. Green compost- and bark-based materials would have the additional advantage of possible pathogen-suppressing activity. The fungicidal properties of bark was reported for several crops, including lilies, by Hoitink (1980) and Hoitink *et al*. (1982).

Compared with the often large effects of different substrates on crop growth, the effect of fertiliser usage was generally less obvious. However, the highest rate of fertiliser used (equivalent to 1.5kg PG-Mix /m^3 of substrate) reduced stem length, and increasing the fertiliser rate increased the numbers of all types of leaf lesions. As a result of these findings, a lower rate of base fertiliser (equivalent to 0.75kg PG-Mix /m^3) was recommended for future use. On balance, it was considered advisable to use a liquid feed routinely to avoid any loss of quality.

In the first year of the project substrate analysis was done according to standard ADAS methods involving water extraction. It has been argued that, while this method is suitable for determining nutrients in substrates composed of peat and inorganic nutrients, it is unsuitable for materials such as green compost-based substrates, which have less soluble nutrients and so would be underestimated. This could lead to over-dosing such materials with nutrients (A.

Rainbow, personal communication). In the second and third years of the project, substrates were extracted using the DTPA/calcium chloride method as well as water extraction. There is no published information (of which the authors are aware) on how to interpret nutrient levels in substrates analysed by the DTPA/calcium chloride method. Although the latter showed higher concentrations of many nutrients, this simply poses another question - what target levels should be aimed for using this method? Since the analysis of substrates by this method has shown that substrates containing a proportion of green compost have greater reserves of slower release nutrients than peat substrates, this could be useful for longer-term crops where it could reduce the need for liquid feeding, hence giving a cost saving.

Although several general conclusions could be drawn from the results, a number of the characteristics and responses observed were cultivar-dependent. It may not be possible to extrapolate from the results obtained with one cultivar to other cultivars in the same group.Thus, only Brunello and Snow Queen produced significant lengths of basal zone, in which respect both cultivars responded positively to using appropriate substrates. At the levels of fertiliser tested, only Snow Queen showed clear effects on overall foliage colour: the foliage was pale where low nutrient levels were used and generally in the non-peat substrates. Leaf lesions (both *Botrytis*-like and scorch types) occurred at a similar frequency in Snow Queen in all treatments, whereas the effects of substrates and fertiliser levels were consistent in increasing or reducing the numbers of lesions in the other three cultivars, despite the different frequency with which lesions occurred in them. Although cv Star Gazer is listed in Dutch information as being sensitive to leaf scorch (International Flowerbulb Centre, undated), in this project it developed few such symptoms. However, a distinct (and unidentified) type of leaf spotting occurred in Star Gazer, again being most frequent with the high fertiliser rate and in the green/coir substrate.

Leaf scorch was the most troublesome disorder found in the experiment. Confirming earlier reports (see Literature Review), there was a high degree of variability in the incidence of leaf scorch between individual plants, even within a treatment. Easter lilies are prone to leaf scorch, so it was interesting to note that cv Snow Queen had a similar number of lesions irrespective of substrate and fertiliser level, while the numbers of lesions in other cultivars were clearly affected by substrate and fertiliser level. As reviewed earlier, leaf scorch appears to be a multifactorial disorder related to both disease (*Botrytis elliptica*) and cultural factors, especially nutrient levels. In this project attempts to isolate *B. elliptica* from any of the three types of lesions observed were unsuccessful, further supporting a primarily nutritional cause of scorch. In general, the results of the reviewed investigations showed that the incidence of scorch could be reduced by applying higher levels of nitrogen, though, in this project, increasing nitrogen, phosphorus and potassium had the opposite effect.

An experiment was carried with another Asiatic lily cultivar, Élite, which is particularly prone to leaf scorch. In Élite, the number of lesions was low in the wood/bark and recycled peat substrates (15 and 18 per stem, respectively), but was very high in the green/coir substrate (56 per stem) and in new peat (99 per stem). This demonstrates there is potential to manage even highly scorch-prone cultivars successfully through the choice of substrate.
A growing phenomenon in bulb- and other cut-flower production in the Netherlands is ‘aquaculture’. Used on a large scale for tulips, aquaculture techniques are likely to be developed for many other flower crops, including lilies which, until recently, have been considered unsuitable for this type of culture because of the need for long-term support and

for allowing stem rooting. However, it is considered that conventional (solid substrate) lily growing will continue to have a place for many years to come, and, indeed, the high degree of capitalisation involved may mean that aquaculture may remain unsuitable for many horticultural enterprises.

Any substrate is, of course, only the sum of its individual properties, and this project is concerned not with just identifying suitable or unsuitable substrates for lily growing, but with defining the critical factors and levels of these factors for the crop. In an attempt to elucidate relationships between plant quality aspects and nutrient levels, however, numerous relationships between substrate properties and crop characteristics were examined, but no strong relationships were found.

ACKNOWLEDGEMENTS

The authors thank the staff of HRI Kirton, especially Rod Asher, for carefully carrying out this work. We thank Andrew Mead (Biometrics Department, HRI Wellesbourne) for the design and analysis of, and helpful comments on, the experiments. We also thank Cheryl Brewster (HRI Stockbridge House) for her interest in the work and for disease diagnostics, Dr Rosemary Collier (HRI Wellesbourne) for aphid identification, Dr Tim O'Neill (ADAS Arthur Rickwood) for fungal pathogen identification, and Winchester Growers Ltd for providing advice and supplies of peat for recycling. We are grateful to the HDC Project Co-ordinators, Dr Gordon Flint (Winchester Growers Ltd.) and Bob Goemans (Parigo Horticulture), and to all the following for their help and advice: Andrew Bly (G.A.Verdegaal & Zonen Export B.V.), Michael Mann, Robert Lacey and Wiley Teubes (Winchester Growers Ltd.), Catherine Dawson (Melcourt Industries Ltd.), Anna Kavanagh (William Sinclair Horticulture Ltd.) and Dr Arnie Rainbow (Rainbow Wilson Associates).

REFERENCES

Aaron, J. R. (1973). Bark: A potentially useful by-product. *Journal of the Institute of Wood Science,* **6,** (3), 22-27.

ADAS (1984). *Lime and fertiliser recommendations. No. 4 Glasshouse crops and nursery stock 1985/86.* Booklet 2194. Ministry of Agriculture, Fisheries and Food (Publications), Alnwick.

Aimone, T. (1986). Culture notes. *GrowerTalks,* **50,** 16.

Ames, R.N and Linderman, R.G (1977). Vesicular-arbuscular mycorrhizae of Easter lily in the northwestern United States. *Canadian Journal of Microbiology*, **23**, 1663-1668.

Ames, R.N and Linderman, R.G (1978). The growth of aster lily (*Lilium longiflorum*) as influenced by vesicular-arbuscular mycorrhizal fungi, *Fusarium oxysporum*, and fertility level. *Canadian Journal of Botany*, **56**, 2773-2780.

Anon. (1987). *The analysis of agricultural materials.* Reference Book 427. 3rd edition. MAFF, London.

Anon. (1990). *Leliegids no. 4 (1989/1990)*. Cooperatieve Nederlandse Bloembollencentral B.A., Lisse.

Aoki, N. and Yoshino, S. (1988). [Studies on the flower production of bulbous plants under computer controlled system. (7) Effects of the amount of dry matter production and the quality of cut flowers of semi-forced lilies] (in Japanese). *Bulletin of the Faculty of Agriculture, Shimane University,* **22,** 37-42.

Argo, W. R. and Biernbaum, J. A. (1994). Irrigation requirements, root-medium pH, and nutrient concentrations of Easter lilies grown in five peat-based media with and without an evaporation barrier. *Journal of the American Society for Horticultural Science,* **119,** 1151-1156.

Baggett, J. R. (1967). Fertilizers for lily seedlings. *The Lily Yearbook of the North American Lily Society,* **20,** 88-96.

Bald, J. G., Kofranek, A. M. and Lunt, O. R. (1955). Leaf scorch and *Rhizoctonia* on Croft lilies. *Phytopathology,* **45,** 156-162.
Beattie, D. J. and White, J. W. (1993). *Lilium* - Hybrids and species. In: *The physiology of flower bulbs* (A. A. De Hertogh and M. Le Nard, Eds). Elsevier, Amsterdam, 424-454.
Beck, R. (1984). The 'hows' and 'whys' of hybrid lilies; establishing a multicolored lily program for cuts and pots. *Florist's Review,* **175,** 22, 24, 27.
Berghoef, J. (1986). Effect of calcium on tipburn of Lilium 'Pirate'. *Acta Horticulturae,* **177,** vol. II, 433-438.
Berghoef, J., Kappelhof, G.S.J. and Willems, B. (1981). Bestrijding bladverbranding bij lelie Pirate vereist verder onderzoek. *Vakblad voor de Bloemisterij*, **36**, (22), 22-23.
Bergman, B. H. H., Eijkman, A. J., Muller, P. J., van Slogteren, D. H. M., Derks, A. F. L. M., and Westeijn, G. (1983). *Ziekten en afwijkingen bij bolgewassen. Deel I: Liliaceae*. Laboratorium voor de Bloembollenonderzoek, Lisse.
Blaney, L. T. and Roberts, A. N. (1967). Bulb production. In: *Easter lilies - The culture, diseases, insects and economics of Easter lilies* (D. C. Kiplinger and R. W. Langhans, Eds). Cornell University Press, Ithaca, 23-36.
Bloemenbureau Holland/VBN (1994). *Rijpheid snijbloemen. Vol. 1*. Vereniging van Bloemenveilingen in Nederland, Leiden.
Boon, J. van der, Niers, H. and Kruijer, C.J. (1984). Blauw-zwartverkleuring in lelie en… kalkbemesting. *Bloembollencultuur,* **94**, 698-699.
Boontjes, J. and Ploegman, C. (1981). Zout beregeningswater en de bolproduktie bij lelies. *Bloembollencultuur,* **91**, (49), 1307.
Bragg, N., Holmes, S. and Lightfoot-Brown, S. (2000). *Peat alternatives - A review of performance, future availability and sustainability for commercial plant production in the UK*. Report to MAFF.
Buschman, J. C. M. (1988). Lilien auch als Topfpflanzen. *Gartnerborse und Gartenwelt,* **88,** 43-47.
Chaplin, M. H. and Roberts, A. N. (1981). Seasonal nutrient element distribution in leaves of Ace and Nellie White cultivars of the Easter lily, *L. longiflorum* L. *Communications in Soil Science and Plant Analyses,* **12,** 227-237.
Choi, J. M. and Lee, C. W. (1995). [Effects of irrigation methods, nutrient concentrations and media on salt accumulation in media, growth and flowering of Easter lilies] (in Korean). *Journal of the Korean Society for Horticultural Science,* **36,** 715-724.
Choi, S. T., Cheong, S. T. and Ahn, H. G. (1996). Effects of planting depth and cold treatment on growth and flowering of *Lilium* hybrid. *Acta Horticulturae,* **414,** 235-242.
Dallon, J., Jr. (1987). Effects of spent mushroom compost on the production of greenhouse-grown crops. *Combined Proceedings, International Plant Propagators' Society,* **37,** 323-329.
De Hertogh, A. A. (1989). *Holland bulb forcer's guide*. 4th Edition. International Flower-Bulb Centre, Hillegom.
Devonald, V.G. (1982). The effect of wood charcoal on *Lilium* 'Destiny' in pot culture. *North American Lily Society Lily Yearbook 1981*, 36-37.
Dunham, C. W. and Crossan, D. F. (1959). Factors in tip-burn injury on leaves of Easter Lilies. *Proceedings of the American Society for Horticultural Science,* **74,** 704-710.
Eastwood, T. (1952). Forcing Creole lilies at different levels of soil nitrate. *Proceedings of the American Society for Horticultural Science,* **59,** 531-541.
Ehlert, P.A.I., de Willigen, P., Oenema, O., Brower, G. and Pasterkamp, H.P. (2000). Fosforbehofte van bloembollen. Resultaten 1997-1998. *Meststoffen 2000*, 53-60.
Everett, T. L. and Nelson, P. V. (1996). Does perlite play a role in fluoride toxicity of floricultural crops? *North Carolina Flower Growers' Bulletin,* **41,** 6-10.
Furuta, F. T., Martin, W. C. and Perry, F. (1963). Lithium toxicity as a cause of leaf scorch in Easter lily. *Proceedings of the American Society for Horticultural Science,* **83,** 803-810.
Furuta, T. (1961). Correlation of incidence of leaf scorch of Easter lilies to nutrient content of the foliage and other observations. *Proceedings of the Association of Southern Agricultural Workers,* **58,** 181.
Gamez, S. E. (1990). *Effect of fertilizer treatment on growth of* Hedera helix *and Asiatic lily hybrids grown with ebb and flow and overhead-drip irrigation*. MSc Thesis, Pennsylvania State University.
Gindina, S.R. (1976). [The effect of fertilizers on the growth and development of *Lilium davidii*] (in Russian). *Ohkrana Sredy i Ratsional'n Ispol'z Rastitel'n Resursov*, (1976), 232-233.
Giustiniani, L., Moschini, E. and Graifenberg, A. (1988). Fabbisogni nutritivi di *Lilium* "Mid Century". *Colture Protette,* **17,** 81-87.

Goldsberry, K. L. and Maffei, H. M. (1986). Response of Easter lilies grown in rockwool, peat-lite and soil media to warm water irrigation. *Research Bulletin, Colorado Greenhouse Growers' Association,* **436,** 3-5.
Gong, X. K., Zhao, X. Y., Chen, X. L., Hou, F. M. and Gao, F. Y. (1996). [Study on improvement of survival rate of lily plantlets from tissue culture transplanted into soil] (in Chinese). *Acta Horticulturae Sinica,* **23,** 73-77.
Hanks, G. R. and Rahn, C. R. (1992). *Bulb forcing: The use of peat substitutes or extenders.* Final report on project BOF 26. Horticultural Development Council, Petersfield.
Hao, W. Y., Lin, X. G., Gu, X. X. and Niu, J. Q. (1991). [Efficiency of VAM fungi and the prospect of their practical application in some soils] (in Chinese). *Acta Pedologica Sinica,* **28,** 129-131.
Hasek, R. (1950). Croft lilies, 1949-50. *Ohio Florists' Association Bulletin*, **248**, (May 1950) (pages not known).
Hasek, R.F. and Farnham, D.S. (1975). Japanese Georgia lily response to zinc. *Flower and Nursery Report*, September/October 1975, 5-7.
Hoitink, H.A. (1980). Composted bark, a lightweight growth medium with fungicidal properties. *Plant Disease,* **64**, 143-147.
Hoitink, H.A.J., Nelson, E.B. and Gordon, D.T. (1982). Composted bark controls soil pathogens of plants. *Ohio Report on Research and Development*, **67**, (1), 7-10.
Holcomb, E. J., Gamez, S., Beattie, D. and Elliott, G. C. (1992). Efficiency of fertigation programs for Baltic ivy and Asiatic lily. *HortTechnology,* **2,** 43-46.
Holmes, R.L. and Coorts, G.D. (1980). Effects of excess manganese nutrition on the growth of Easter lily. *HortScience,* **15**, 497-498.
Hwang, K. S., Park, J. M., Yiem, M. S. and Ho, Q. S. (1998). [Effect of high salt concentration on the growth of lily in plastic film house soil] (in Korean). *RDA Journal of Agro Environment Science*, **40,** 1-5.
International Flower Bulb Centre (undated). *Forcing flower bulbs*. International Flower Bulb Centre, Hillegom.
International Flowerbulb Centre (undated). *Manual for the selection of bulbflower cultivars. Part II.* International Flowerbulb Centre, Hillegom.
Jiao, J., Tsujita, M. J. and Murr, D. P. (1986). Effects of paclobutrazol and A-Rest on growth, flowering, leaf carbohydrate, and leaf senescence in 'Nellie White' Easter lily (*Lilium longiflorum* Thunb.). *Scientia Horticulturae,* **30,** 135-141.
Johnson, E.W. (1980). Comparison of methods of analysis for loamless composts. *Acta Horticulturae*, **99**, 197-204.
Kiplinger, D.C., Tayama, H.K. and Staby, G. (1972). Slow-release fertilizers and fertilizer injection on growth of several lily cultivars. *Ohio Florists' Association Bulletin,* no. 509, 9.
Kiplinger, D.C., Tayama, H.K. and Staby, G. (1975). Watering frequency as it affects flower bud count on Easter lily. *Ohio Florists' Association Bulletin*, no. 543, 6.
Klasman, R., Moreira, D. and di Benedetto, A. (2002). Cultivo de hibridos asiaticos de *Lilium* sp. en tres sustratos diferentes. *Revista de la Facultad de Agronomia (Universidad de Buenos Aires),* **22**, 79-83.
Kohl, H. C., Jr., Lunt, O. R. and Kofranek, A. M. (1960). Response of *Lilium longiflorum* var. Croft to high salt and boron concentrations. *Proceedings of the American Society for Horticultural Science,* **76,** 644-648.
Kohl, H. C. and Oertli, J. J. (1961). Distribution of boron in leaves. *Plant Physiology,* **36,** 420-424.
Koths, J.S. and Gledhill, B. (1978). The effects of various levels of manganese on Easter lilies. *Connecticut Greenhouse Newsletter,* no. 88, 16-17.
Kruijer, C.J. (1982). Grondontsmetting en bemesting bij intensieve teelt van *Lilium speciosum* (1), (2). *Bloembollencultuur*, **92**, 876-877, 894-895.
Larson, R. A., Thorne, C. B., Milks, R. R., Isenberg, Y. M. and Brisson, L. D. (1987). Use of ancymidol bulb dips to control stem elongation of Easter lilies grown in a pine bark medium. *Journal of the American Society for Horticultural Science,* **112,** 773-777.
Lewis, A. J. and Gilbertz, D. A. (1987). Hybrid lily response to various methods of ancymidol application. *Acta Horticulturae,* **205,** 237-247.
Levi-Minzi, R., Riffaldi, R., Saviozzi, A. and Maggiore, G. (1993). Le colture florcole in serra e la salinita del terreno. *Colture Protette*, **22**, 83-86.
Lin, S. C., Wu, C. G., Huang, S. N. and Houng, K. H. (1999). [Inoculation effect of arbuscular mycorrhizal fungi and phosphate-solubilizing bacteria on the growth of Asian hybrid lily] (in Chinese). *Journal of Agricultural Research of China,* **48,** 135-142.
Liu, T. S. (1996). [Effect of organic matters on the occurrence of the bulb mites on bulb crops] (in Chinese). *Bulletin of Taichung District Agricultural Improvement Station,* **51,** 49-57.

Logan, T.J., Faber, W.R. and Smith, E.M. (1984). Use of composted sludge on different crops. *Ohio Report on Research and Development in Agriculture, Home Economics, and Natural Resources*, **69**, 37-40.

Lopez Mosquera, M. E., Ruano Prieto, A. and Martinez Cortizas, A. (1994). Produccion de *Lilium* cv. "Connectikut King" en diferentes sustratos. *Investigacion Agraria, Produccion y Proteccion Vegetales,* **9,** 193-200.

MAFF (1984). *Bulb and corm production.* Reference book 62. Her Majesty's Stationery Office, London.

MAFF (2000). *Glasshouse crops survey, area and production in 1999. England and Wales (registered agricultural holdings only)*. MAFF/Government Statistical Service, York.

Marshall, P.A., Joiner, J.N. and Witte, W.T. (1975). Effect of media, fertilizer rate and ancymidol on Mid-Century hybrid lily 'Enchantment'. *Proceedings of the Florida State Horticultural Society,* **87,** 493-495.

Marousky, F.J. (1979). Classical leaf scorch: boron or fluoride. *North American Lily Society Lily Yearbook 1978*, 55-59.

Marousky, F. J. (1981). Symptomology of fluoride and boron injury in Lilium longiflorum Thunb.. *Proceedings of the American Society for Horticultural Science,* **106**, 341-344.

Marousky, F. J. and Woltz, S. S. (1976). Incidence of leaf scorch in hybrid lilies as influenced by fluoride and superphosphate. *Proceedings of the Florida State Horticultural Society,* **88,** 612-615.

Marousky, F. J. and Woltz, S. S. (1977). The influence of lime, nitrogen, and phosphorus sources on the availability and relationship of soil fluoride to leaf scorch in *Lilium longiflorum* Thunb. *Proceedings of the American Society for Horticultural Science,* **102,** 799-804.

Marousky, F. J. and Woltz, S. S. (1979). Leaf scorch in Asiatic hybrid lilies. *Proceedings of the Florida State Horticultural Society,* **91,** 201-204.

McKenzie, K. (1989). Potted lilies made easy: The new, naturally short Asiatic lily varieties. *GrowerTalks,* **52,** 48-58.

McWhorter, E. P. and Anderson, C. J. (1951). Diseases in Croft lily plantings, 1949-50. *Plant Disease Reporter,* **35,** 106-108.

Miles, L. E. (1952). An investigation into the effects of mineral deficiencies in the Easter lily. *Lily Yearbook,* **16,** 79-83.

Miller, R.O. (1991). Lilies. In: *Ball red book, 15th edition* (V. Ball, Ed). George J. Ball Publisher, West Chicago, 625-651.

Miller, W. B. (1993). *Lilium longiflorum*. In: *The physiology of flower bulbs* (A. A. De Hertogh and M. Le Nard, Eds). Elsevier, Amsterdam, 391-422.

Nederpel, W.A.C. (1979). Voorzichtig met flour bij lelies. *Vakblad voor de Bloemisterij*, **34**, (37), 44-45.

Niers, H. and van der Boon, J. (1986). Zavelgrond stelt andere eisen dan zand. Stikstofbehoeft Enchantment vastgesteld. *Bloembollencultuur,* **97,** 8-9.

Norris, I. (1988). *Lily bulb production.* Leaflet P 3139. Ministry of Agriculture, Fisheries and Food (Publications), Alnwick.

Oertli, J.J. (1994). Non-homogeneity of boron distribution in plants and consequences for foliar diagnosis. *Communications in Soil Science and Plant Analysis*, **25**, 1133-1147.

Ohkawa, K. (1977). *Studies on the physiology and control of flowering in* Lilium speciosum rubrum. Special Bulletin, Kanagawa Horticulture Experiment Station.

Pertuit, A. J., Jr. (1973). Effects of lighting Easter lily bulbs during cold treatment on plant growth and flowering. *Journal of the American Society for Horticultural Science,* **98,** 534-536.

Pertuit, A. J., Jr. and Kelly, J. W. (1987). Timing of a lighting period for Easter lily bulbs prior to forcing. *HortScience,* **22,** 316.

Powell, M.V., Widmer, R.E. and Wilkins, H.F. (1975). 'Nellie White' Easter lily fertilizer and growth media studies. Minnesota State Florists' Bulletin, December 1975, 4-13.

Prince, T. A. and Cunningham, M. S. (1989). Production and storage factors influencing quality of potted Easter lilies. *HortScience,* **24,** 992-994.

Rainbow, A., Wilson, N. and Szmidt, R.A.K. (1998). The transformation of composted organic residues into effective growing media. *Acta Horticulturae,* **469**, 79-88.

Riddiough, S. (1999). *Wood residue: Waste or resource?* Timber Research and Development Association.

Roberts, A. N., Blaney, L. T. and Compton, O. C. (1964). Seasonal changes of certain nutrient elements in the leaves and bulbs of 'Croft' lily, *Lilium longiflorum*, and their relation to bulb yield. *Proceedings of the American Society for Horticultural Science,* **85,** 611-630.

Roberts, A. N. and Moeller, F. W. (1979). Evidence of genetic evidence of leaf scorch in *Lilium longiflorum*. *The Lily Yearbook of the North American Lily Society,* **32,** 50-54.

Roberts, A. N., Stephensen, R. E. and Wadsworth, S. E. (1951). Effectiveness of lime in preventing scorch of Croft lilies during forcing. *Florists' Exchange and Horticultural Trade World***,** (27 October 1951), 14-15.

Roberts, A. N., Stephensen, R. E., Wadsworth, S. E., McWhorter, F. P. and Stuart, N. W. (1951). Effects of fertilizers on growth, bud-count, and leaf scorch of Croft lilies. *Florists' Review***,** (3 May 1951), 25-27.

Roorda van Eysinga, J. P. N. L. (1974). De opname van fluoride door de wortel en de gevolgen daarvan diverse gewassen, in het bijonder fresia. *Verslagen van Landbouwkundige Onderzoekingen*, no, 821, 83pp.

Roorda van Eysinga, J. P. N. L. (1980). Leaf scorch in lilies due to fluorine. *Vakblad voor de Bloemisterij,* **35** (48), 31.

Scheffer, R. P. and Haney, W. J. (1956). Causes and control of root rot in Michigan greenhouses. *Plant Disease Reporter*, **40,** 570-579.

Seeley, J. G. (1950). Mineral nutrition deficiencies and leaf burn of Croft Easter lilies. *Proceedings of the American Society of Horticultural Science,* **56,** 439-445.

Seeley, J. G. and Velasquez, D. de C. (1952). The effect of fertiliser applications on leaf burn and growth of Croft lilies. *Proceedings of the American Society for Horticultural Science,* **60,** 459-472.

Selmar-Olsen, A. R., Sant, M. D., Giselrod, H. R. and Solbraa, K. (1983). Nitrogen balance in bark composts used as growing media. *Acta Horticulturae,* **150**, 193-202.

Shanks, J. B. and Link, C. B. (1959). Leaf scorch and the Croft lily. *Proceedings of the American Society for Horticultural Science,* **73,** 503-511.

Slangen, J. H. G., Hendriks, C. H. M. and Hof, N. A. (1987). *Stikstofbemesting bij lilies.* Rapport 61. Laboratorium voor de Bloembollenonderzoek, Lisse.

Slangen, J. H. G., Krook, G. J., Hendriks, C. H. M. and Hof, N. A. A. (1989). Nitrogen dressing and nutrient absorption of lilies (Asiatic hybrids) on sandy soils. *Netherlands Journal of Agricultural Science,* **37,** 269-272.

Smith, C. (1995). Coir: A viable alternative to peat for potting? *The Horticulturist,* **4,** (3), 12, 25-28.

Sonneveld, C., Baas, R., Nijssen, H. M. C. and de Hoog, J. (1999). Salt tolerance of flower crops grown in soilless culture. *Journal of Plant Nutrition,* **22,** 1033-1048.

Stuart, N. W. (1949). Leaf burn of Croft Easter Lilies linked to nutrients. *Florists' Review,* **104,** 23-24.

Stuart, N. W., Skou, W. and Kiplinger, D. L. (1952). Further studies on cause and control of leaf scorch of Croft Easter lily. *Proceedings of the American Society for Horticultural Science,* **60,** 434-438.

Swaine, D.J. (1962). *The trace element content of fertilisers.* Technical Communication no. 52. Commonwealth Bureau of Soils, Harpenden.

Szlachetka, W. I., Wojcik, B. and Prabucki, A. (1997). Wplyw roznych podlozy i nawozenia mineralnego na kwitnienie lilii cv. 'Star Gazer' uprawianych w szklarni. *Zeszyty Problemowe Postepow Nauk Rolniczych,* **449,** 199-212.

Tizio, M. and Seeley, J.G. (1976). Leaf scorch of 'Ace' lilies as affected by nitrogen fertilizer source and fluoride application. *New York State Flower Industries Bulletin,* no. 74, 1, 3, 5, 8.

Tompsett, A. A. (1984). *Lilies.* Leaflet 859. Ministry of Agriculture, Fisheries and Food (Publications), Alnwick.

Tosi, D. (1984). Preliminary investigations on the removal of nutrient elements in Mid-century *Lilium* and *Lilium speciosum rubrum*. *Notiziario di Ortoflorofruitticoltura,* **10,** 135-138.

Treder, J. (2001). The effect of light and nutrition on growth and flowering of oriental lilies. *Acta Horticulturae,* **548**, 523-528.

Tsujita, M. J., Murr, D. P. and Johnson, A. G. (1978). Influence of phosphorus nutrition and ancymidol on leaf senescence and growth of Easter lily. *Canadian Journal of Plant Science,* **58,** 287-290.

Tsujita, M. J., Murr, D. P. and Johnson, A. G. (1979). Leaf senescence of Easter lily as influenced by root/shoot growth, phosphorus nutrition and ancymidol. *Canadian Journal of Plant Science*, **59,** 757-761.

Tu, C. C., Hsieh, T. F. and Tsai, W. H. (1991). [Effects of temperature, moisture and amendments on the occurrence of lily southern blight caused by *Sclerotium rolfsii* Sacc.] (in Chinese). *Plant Protection Bulletin Taipei,* **33,** 80-94.

Tu, C. C., Hsieh, T. F. and Tsai, W. H. (1992). [Studies on control of lily southern blight by application of soil amendments] (in Chinese). *Journal of Agricultural Research of China,* **41,** 280-294.

Turner, J. (1990). *Pot-plant production of Asiatic lilies.* M.Sc. Thesis, Pennsylvania State University.

van der Boon, J. and Niers, H. (1986). Effect of nitrogen on bulb production, forcing quality of the bulb and vase life of the flower of *Lilium* 'Enchantment'. *Acta Horticulturae,* **177,** vol. I, 249-254.

van der Boon, J. and Niers, H. (1987). *Effect van stikstofbemesting bij* Lilium *'Enchantment' op zandgrond en lichte zavel: opbrengst, broeikwaliteit en houdbaarheid van de bloem.* Rapport 2-87. Instituut voor

Bodemvruchtbaarheid, Haren.
van der Boon, J., Niers, H. and Kruyer, C. J. (1983). The lily cv. Enchantment nitrogen manuring in sandy soil and uptake of nutrients. *Bedrijfsontwikkeling,* **14** (1), 77-80.
van Tuyl, J. M. and Kwakkenbos, T. A. M. (1986). Effect of low light intensity on flowering of Asiatic lilies. *Acta Horticulturae,* **177**, 607-611.
Weidner, M. (1977). Dungung von Lilien. *Deutscher Gartenbau*, **31**, 1092-1094.
White, H. E. (1940). The culture and forcing of Easter Lilies. *Massachusetts Agricultural Experiment Station, Bulletin No. 376.*
Woltz, S.S. and Marousky, F.J. (1976). Fluoride leaf scorch of lily and gladiolus: soil acidity, superphosphate and diagnostic techniques. *Proceedings of the Florida State Horticultural Society*, **88**, 609-612.
Wu, C. G. and Lin, S. C. (2000). [Inoculation effect of arbuscular mycorrhizal fungi on the growth and phosphorus contents of oriental lily bulb] (in Chinese). *Journal of Agricultural Research of China,* **49,** 50-56.
Wu, C. G., Lin, S. C., Lin, M. L., Wu, G. D. and Chen, W. H. (1999). [Influence of biocides and fertilizers on the VA mycorrhizal inoculation and bulblet growth of Oriental lily] (in Chinese). *Journal of Agricultural Research of China,* **48,** 128-134.
Wu, G. D., Liu, W. C., Chang, J. Y., Yao, T. P., Chen, J. B. and Chen, W. H. (1999). [A mixed medium of filter cake and rice hull for cultivation of *Lilium* "Casa Blanca" bulbs] (in Chinese). *Report of the Taiwan Sugar Research Institute,* **163,** 33-44.
Yoshiba, M., Aso, S. and Hosoya, T. (1981). [Nutrition and physiology of ornamental flowering plants. Part I. Influence of the ratio of nitrate nitrogen and ammonium nitrogen on growth and mineral absorption] (in Japanese). *Journal of Agricultural Science Japan*, **26**, 68-81.

HDC Project PC/BOF 140
Final Report (July 2003)

LILIES: NUTRITION OF GLASSHOUSE BULBS IN PEAT-FREE AND RECYCLED PEAT SUBSTRATES

APPENDICES

APPENDIX A: CROP RESULTS

Table A1. 2000 experiment. Cropping dates and cropping duration: main effect means and significance[1] of effects and interactions

	Cropping dates (day numbers)			*Days from 10 to 90% crop*
	First crop	*Mean date*	*Last crop*	
Cultivar				
Brunello	200.5	203.7	207.5	4.8
Royal Fantasy	214.1	215.6	217.2	2.5
Snow Queen	222.5	224.4	225.9	2.6
Star Gazer	229.1	230.9	233.3	3.3
SED (3 df)	*0.25*	*0.18*	*0.32*	*0.17*
Substrate				
1. Peat	216.7	218.8	221.3	3.3
2. Peat/used peat	216.6	218.8	221.2	3.3
3. Used peat	217.1	218.8	221.0	3.0
4. Wood/bark	216.1	218.2	220.3	3.1
5. Wood/bark/green	215.9	218.0	220.3	3.3
6. Green/coir	216.9	219.2	221.6	3.7
SED peat v. others (172 df)	*0.17*	*0.10*	*0.23*	*0.19*
SED between others (172 df)	*0.20*	*0.12*	*0.26*	*0.21*
Fertiliser				
Low	216.2	218.4	220.7	3.3
Medium	216.7	218.7	221.0	3.2
High	216.8	218.9	221.2	3.3
SED (172 df)	*0.13*	*0.08*	*0.17*	*0.14*
Significance				
Cultivar (C)	***	***	***	**
Substrate (S)	***	***	***	*
Fertiliser (F)	***	***	*	ns
C x S	**	***	ns	*
C x F	***	***	***	**
S x F	*	***	*	ns
C x S x F	ns	ns	ns	ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A2. 2000 experiment. Stem lengths and weights: main effect means and significance[1] of effects and interactions. For lengths and stem weight, the data were analysed after log-transformation, and the back-transformed values are shown in parenthesis

	Length (mm)						*Overall stem weight (g)*		*Stem density (g/cm)*
	Basal stem[2]		*Stem*		*Overall*[3]				
Cultivar									
Brunello	4.90	(133)	6.84	(937)	7.04	(1142)	5.21	(183)	0.16
Royal Fantasy	0.79	(2)	6.44	(627)	6.70	(809)	4.73	(113)	0.14
Snow Queen	2.17	(8)	6.84	(932)	7.00	(1099)	4.90	(134)	0.12
Star Gazer	0.41	(1)	6.30	(543)	6.69	(802)	4.55	(95)	0.12
SED (3 df)	*0.466*	-	*0.019*	-	*0.017*	-	*0.008*	-	*0.001*
Substrate									
Peat	1.55	(35)	6.60	(732)	6.85	(942)	4.83	(125)	0.13
Peat/used peat	2.22	(45)	6.60	(737)	6.85	(946)	4.83	(125)	0.13
Used peat	2.25	(45)	6.61	(745)	6.87	(958)	4.83	(126)	0.13
Wood/bark	2.14	(41)	6.62	(751)	6.87	(961)	4.96	(143)	0.15
Wood/bark/green	2.25	(41)	6.61	(746)	6.87	(964)	4.87	(131)	0.14
Green/coir	2.50	(56)	6.58	(725)	6.84	(937)	4.78	(119)	0.13
SED peat v. others (172 df)	*0.249*	-	*0.006*	-	*0.005*	-	*0.011*	-	*0.001*
SED between others (172 df)	*0.287*	-	*0.007*	-	*0.006*	-	*0.013*	-	*0.002*
Fertiliser									
Low	2.40	(48)	6.62	(751)	6.87	(961)	4.85	(127)	0.13
Medium	2.03	(42)	6.61	(743)	6.86	(956)	4.86	(129)	0.14
High	1.77	(37)	6.58	(721)	6.84	(934)	4.83	(126)	0.14
SED (172 df)	*0.188*	-	*0.005*	-	*0.004*	-	*0.008*	-	*0.001*
Significance									
Cultivar (C)	***		***		***		***		***
Substrate (S)	ns		***		***		***		***
Fertiliser (F)	ns		***		***		***		*
C x S	***		***		***		***		***
C x F	ns		***		***		***		ns
S x F	*		***		***		***		***
C x S x F	ns		***		***		***		ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability
[2]Basal stem is length of lower stem with yellowing or dead leaves
[3]Length of stem plus inflorescence

Table A3. 2000 experiment. Floret numbers: main effect means and significance[1] of effects and interactions. These data were analysed after log-transformation, and the back-transformed values are shown in parenthesis.

	No. viable florets/stem		*No. aborted florets/stem*	
Cultivar				
Brunello	1.99	(7.0)	-0.526	(0.22)
Royal Fantasy	1.50	(4.1)	-0.949	(0.01)
Snow Queen	1.05	(2.5)	-0.978	(0)
Star Gazer	1.44	(3.9)	-0.969	(0)
SED (3 df)	*0.015*	-	*0.0125*	-
Substrate				
Peat	1.49	(4.1)	-0.852	(0.05)
Peat/used peat	1.49	(4.1)	-0.822	(0.06)
Used peat	1.49	(4.1)	-0.879	(0.04)
Wood/bark	1.57	(4.4)	-0.945	(0.01)
Wood/bark/green	1.48	(4.0)	-0.892	(0.03)
Green/coir	1.45	(3.9)	-0.746	(0.10)
SED peat v. others (172 df)	*0.012*	-	*0.0397*	-
SED between others (172 df)	*0.013*	-	*0.0458*	-
Fertiliser				
Low	1.49	(4.0)	-0.854	(0.05)
Medium	1.49	(4.1)	-0.849	(0.05)
High	1.51	(4.1)	-0.864	(0.05)
SED (172 df)	*0.009*	-	*0.0300*	-
Significance				
Cultivar (C)	***		***	
Substrate (S)	***		***	
Fertiliser (F)	ns		ns	
C x S	***		***	
C x F	ns		ns	
S x F	***		ns	
C x S x F	ns		ns	

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A4. 2000 experiment. Foliage colour and lesions: main effect means and significance[1] of effects and interactions. These data were analysed after log-transformation, and the back-transformed values are shown in parenthesis

	Foliage colour score[2]		*No. lesions per stem*[3]	
Cultivar				
Brunello	0.333	(1.02)	0.341	(1.03)
Royal Fantasy	0.322	(1.01)	2.009	(7.08)
Snow Queen	0.486	(1.25)	1.720	(5.21)
Star Gazer	0.332	(1.02)	-0.436	(0.27)
SED (3 df)	*0.0139*	-	*0.1500*	-
Substrate				
Peat	0.337	(1.03)	1.486	(4.05)
Peat/used peat	0.353	(1.05)	0.663	(1.57)
Used peat	0.355	(1.05)	0.478	(1.24)
Wood/bark	0.356	(1.05)	0.385	(1.10)
Wood/bark/green	0.424	(1.15)	0.698	(1.64)
Green/coir	0.417	(1.14)	1.161	(2.82)
SED peat v. others (172 df)	*0.0157*	-	*0.0651*	-
SED between others (172 df)	*0.0181*	-	*0.0751*	-
Fertiliser				
Low	0.411	(1.13)	0.525	(1.32)
Medium	0.354	(1.05)	1.014	(2.38)
High	0.339	(1.03)	1.186	(2.90)
SED (172 df)	*0.0118*	-	*0.0492*	-
Significance				
Cultivar (C)	**		**	
Substrate (S)	***		***	
Fertiliser (F)	***		***	
C x S	***		***	
C x F	***		***	
S x F	**		***	
C x S x F	***		***	

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability
[2]Foliage colour scored from 1 (normal green) to 3 (very pale)
[3]Combined count of scorch and *Botrytis*–like lesions

Table A5. 2000 experiment. Crop performance of lily cultivar Élite in six substrates (all at medium fertiliser rates)[1]. Except for mean crop date and stem density, these data were analysed after log-transformation, and the back-transformed values are shown in parenthesis.

	Mean crop date (day no.)	*Stem length (mm)*		*Stem weight (g)*		*Stem density (g/cm)*	*Length of basal stem[2] (mm)*	
Peat	208.7	6.76	(864)	4.68	(107)	0.101	2.63	(13.5)
Peat/used peat	209.5	6.74	(843)	4.68	(108)	0.105	2.72	(14.8)
Used peat	208.9	6.75	(856)	4.66	(106)	0.101	2.33	(9.9)
Wood/bark	208.4	6.80	(896)	4.81	(123)	0.114	2.14	(8.1)
Wood/bark/green	207.8	6.80	(900)	4.79	(120)	0.109	1.98	(6.8)
Green/coir	208.9	6.72	(826)	4.63	(103)	0.102	2.76	(15.5)
SED peat v. others (13 df)	*0.26*	*0.014*	-	*0.024*	-	*0.0021*	*0.482*	-
SED between others (13 df)	*0.30*	*0.011*	-	*0.028*	-	*0.0025*	*0.557*	-
Significance	**	***		***		***	ns	

Continued below

	Florets per stem		*Number of lesions per stem*					
			Leaf scorch		Botrytis-*like*		*Total*	
Peat	1.99	(7.0)	3.51	(33.0)	4.60	(99.1)	4.89	(132.2)
Peat/used peat	1.98	(6.9)	2.68	(14.2)	3.29	(26.4)	3.71	(40.7)
Used peat	1.95	(6.6)	2.34	(10.0)	2.90	(17.9)	3.35	(28.1)
Wood/bark	2.04	(7.3)	2.02	(7.2)	2.69	(14.3)	3.09	(21.5)
Wood/bark/green	1.97	(6.8)	2.16	(8.3)	3.75	(42.2)	3.94	(50.9)
Green/coir	1.95	(6.7)	3.08	(21.4)	4.02	(55.4)	4.35	(77.0)
SED peat v. others (13 df)	*0.023*	-	*0.128*	-	*0.101*	-	*0.094*	-
SED between others (13 df)	*0.027*	-	*0.148*	-	*0.117*	-	*0.108*	-
Significance	*		***		***		***	

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A6. 2001 experiment: Cropping dates and cropping duration: main effect means and significance[1] of effects and interactions.

	Cropping dates (day numbers)			*Days from 10 to 90% crop*
	First crop	*Mean date*	*Last crop*	
Cultivar				
Brunello	207.3	209.5	212.0	3.7
Royal Fantasy	217.3	218.5	219.7	2.0
Snow Queen	235.9	237.2	239.1	2.5
Star Gazer	231.0	233.0	235.0	3.3
SED (3 df)	*0.18*	*0.13*	*0.12*	*0.15*
Substrate				
1. Peat	223.0	224.8	226.6	2.8
2. Green/wood 1:3	222.9	224.6	226.7	2.9
3. Green/wood 1:1	222.6	224.2	226.1	2.6
4. Wood/bark	222.9	224.6	226.4	2.8
SED (184 df)	*0.11*	*0.08*	*0.16*	*0.14*
Fertiliser				
Low	222.8	224.5	226.3	2.7
Medium	222.9	224.5	226.4	2.8
High	222.9	224.7	226.6	2.9
SED (184 df)	*0.09*	*0.07*	*0.14*	*0.12*
Liquid feed				
Yes	222.9	224.6	226.5	2.8
No	222.8	224.5	226.7	2.7
SED (184 df)	*0.08*	*0.05*	*0.11*	*0.10*
Significance				
Cultivar (C)	***	***	***	**
Substrate (S)	**	***	**	ns
Fertiliser (F)	ns	**	*	ns
Liquid feed (LF)	ns	*	ns	ns
C x S	ns	***	*	ns
C x F	ns	ns	ns	ns
S x F	ns	*	ns	ns
C x LF	ns	**	ns	ns
S x LF	ns	ns	ns	ns
F x LF	ns	ns	ns	ns
C x S x F	ns	ns	ns	ns
C x S x LF	ns	ns	ns	ns
C x F x LF	ns	ns	ns	ns
S x F x LF	ns	ns	ns	ns
C x S x F x LF	ns	ns	ns	ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A7. 2001 experiment. Stem lengths and weights: main effect means and significance[1] of effects and interactions. For stem length and overall stem length and weight, the data were analysed after log-transformation, and the back-transformed values are shown in parenthesis.

	Length (mm)					*Overall stem weight (g)*		*Stem density (g/cm)*
	Basal stem[2]	*Stem*		*Overall*[3]				
Cultivar								
Brunello	109.0	6.72	(826)	6.92	(1014)	5.08	(161)	0.16
Royal Fantasy	4.7	6.23	(507)	6.53	(685)	4.48	(88)	0.13
Snow Queen	8.1	6.69	(806)	6.86	(954)	4.77	(117)	0.12
Star Gazer	5.1	6.27	(527)	6.62	(752)	4.54	(93)	0.12
SED (3 df)	*3.51*	*0.007*	-	*0.008*	-	*0.013*	-	*0.003*
Substrate								
1. Peat	24.7	6.48	(650)	6.75	(855)	4.73	(113)	0.13
2. Green/wood 1:3	38.4	6.47	(648)	6.73	(835)	4.73	(113)	0.14
3. Green/wood 1:1	36.9	6.45	(634)	6.69	(808)	4.57	(96)	0.12
4. Wood/bark	26.8	6.51	(668)	6.76	(864)	4.84	(126)	0.15
SED (184 df)	*2.37*	*0.006*	-	*0.006*	-	*0.012*	-	*0.001*
Fertiliser								
Low	33.8	6.48	(652)	6.73	(840)	4.68	(107)	0.13
Medium	30.8	6.48	(650)	6.74	(842)	4.72	(112)	0.13
High	30.7	6.47	(647)	6.73	(839)	4.75	(115)	0.14
SED (184 df)	*2.06*	*0.005*	-	*0.005*	-	*0.01*	-	*0.001*
Liquid feed								
Yes	24.6	6.48	(655)	6.75	(852)	4.78	(118)	0.14
No	38.9	6.47	(645)	6.72	(829)	4.66	(105)	0.13
SED (184 df)	1.68	0.004	-	0.004	-	0.008	-	0.001
Significance								
Cultivar (C)	***	***		***		***		**
Substrate (S)	***	***		***		***		***
Fertiliser (F)	ns	ns		ns		***		***
Liquid feed (LF)	***	***		***		***		***
C x S	***	***		***		***		***
C x F	ns	**		*		**		***
S x F	ns	***		***		***		**
C x LF	***	***		***		**		ns
S x LF	***	***		***		***		***
F x LF	*	ns		ns		*		ns
C x S x F	ns	***		***		***		**
C x S x LF	**	*		*		***		ns
C x F x LF	*	*		ns		ns		ns
S x F x LF	*	ns		ns		ns		ns
C x S x F x LF	ns	ns		ns		ns		ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability
[2]Basal stem is length of lower stem with yellowing or dead leaves
[3]Length of stem plus inflorescence

Table A8. 2001 experiment. Floret numbers: main effect means and significance[1] of effects and interactions.

	No. viable florets/stem	*No. aborted florets/stem*
Cultivar		
Brunello	7.0	0.2
Royal Fantasy	4.0	0.1
Snow Queen	2.4	0.1
Star Gazer	3.4	0
SED (3 df)	*0.02*	*0.02*
Substrate		
1. Peat	4.3	0.1
2. Green/wood 1:3	4.2	0.1
3. Green/wood 1:1	4.0	0.2
4. Wood/bark	4.4	0.1
SED (184 df)	*0.04*	*0.01*
Fertiliser		
Low	4.1	0.1
Medium	4.2	0.1
High	4.3	0.1
SED (184 df)	*0.03*	*0.01*
Liquid feed		
Yes	4.3	0.1
No	4.1	0.1
SED (184 df)	*0.03*	*0.01*
Significance		
Cultivar (C)	***	**
Substrate (S)	***	***
Fertiliser (F)	***	ns
Liquid feed (LF)	***	***
C x S	***	***
C x F	ns	ns
S x F	ns	ns
C x LF	ns	***
S x LF	ns	***
F x LF	ns	ns
C x S x F	*	***
C x S x LF	ns	*
C x F x LF	ns	ns
S x F x LF	*	ns
C x S x F x LF	ns	ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A9. 2001 experiment. Foliage colour and lesions: main effect means and significance[1] of effects and interactions. The number of lesions was analysed after log-transformation, and the back-transformed values are shown in parenthesis

	Foliage colour score[2]	*Total number lesions per stem*[3]	
Cultivar			
Brunello	1.59	0.12	(0.75)
Royal Fantasy	1.64	0.24	(0.89)
Snow Queen	1.58	1.33	(3.40)
Star Gazer	1.24	-0.73	(0.11)
SED (3 df)	*0.024*	*0.080*	-
Substrate			
1. Peat	1.05	1.26	(3.17)
2. Green/wood 1:3	1.68	-0.21	(0.43)
3. Green/wood 1:1	2.16	-0.46	(0.26)
4. Wood/bark	1.16	0.36	(1.06)
SED (184 df)	*0.038*	*0.060*	-
Fertiliser			
Low	1.66	-0.05	(0.58)
Medium	1.48	0.24	(0.89)
High	1.40	0.53	(1.32)
SED (184 df)	*0.033*	*0.050*	-
Liquid feed			
Yes	1.20	0.27	(0.93)
No	1.83	0.21	(0.86)
SED (184 df)	*0.027*	*0.040*	-
Significance			
Cultivar (C)	***	***	
Substrate (S)	***	***	
Fertiliser (F)	***	***	
Liquid feed (LF)	***	ns	
C x S	***	***	
C x F	**	***	
S x F	**	***	
C x LF	***	***	
S x LF	***	ns	
F x LF	**	ns	
C x S x F	**	***	
C x S x LF	**	ns	
C x F x LF	ns	ns	
S x F x LF	***	ns	
C x S x F x LF	ns	ns	

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability
[2]Foliage colour scored from 1 (normal green) to 3 (very pale)
[3]Combined count of scorch and *Botrytis*–like lesions

Table A10. 2001 experiment. Foliage lesions: main effect means and significance[1] of effects and interactions. These data were analysed after log-transformation, and the back-transformed values are shown in parenthesis

	Number scorch lesions/stem		*Number* Botrytis *lesions/stem*	
Cultivar				
Brunello	-0.12	(0.513)	-0.34	(0.335)
Royal Fantasy	-0.11	(0.521)	-0.06	(0.570)
Snow Queen	1.26	(3.164)	-0.40	(0.293)
Star Gazer	-0.86	(0.048)	-0.83	(0.060)
SED (3 df)	*0.078*	-	*0.051*	-
Substrate				
1. Peat	0.96	(2.239)	0.38	(1.086)
2. Green/wood 1:3	-0.32	(0.354)	-0.83	(0.063)
3. Green/wood 1:1	-0.51	(0.224)	-0.90	(0.031)
4. Wood/bark	0.04	(0.670)	-0.29	(0.374)
SED (184 df)	*0.053*	-	*0.049*	-
Fertiliser				
Low	-0.20	(0.448)	-0.63	(0.156)
Medium	0.07	(0.695)	-0.42	(0.285)
High	0.26	(0.920)	-0.18	(0.462)
SED (184 df)	*0.046*	--	*0.043*	-
Liquid feed				
Yes	0.09	(0.722)	-0.41	(0.290)
No	-0.01	(0.620)	-0.41	(0.289)
SED (184 df)	*0.037*	-	*0.035*	-
Significance				
Cultivar (C)	***		**	
Substrate (S)	***		***	
Fertiliser (F)	***		***	
Liquid feed (LF)	**		ns	
C x S	***		***	
C x F	***		***	
S x F	***		***	
C x LF	***		ns	
S x LF	ns		ns	
F x LF	ns		ns	
C x S x F	***		***	
C x S x LF	ns		ns	
C x F x LF	ns		ns	
S x F x LF	ns		ns	
C x S x F x LF	ns		ns	

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A11. 2002 experiment: Cropping dates and cropping duration: main effect means and significance[1] of effects and interactions

	Cropping dates (day numbers)			*Days from 10 to 90% crop*
	First crop	*Mean date*	*Last crop*	
Cultivar				
Brunello	196.6	199.9	202.6	4.5
Star Gazer	220.2	222.3	224.6	3.4
SED (2 df)	*0.22*	*0.31*	*0.34*	*0.17*
Substrate				
1. Peat	208.2	211.1	213.4	4.0
2. Green/wood 1:3	208.3	210.9	213.3	3.7
3. Green/wood 1:1	208.6	211.2	213.9	4.0
4. Wood/bark	208.5	211.2	213.8	4.0
SED (44 df)	*0.30*	*0.14*	*0.33*	*0.41*
Usage of substrate				
New	208.1	210.8	213.7	4.1
Re-cycled	208.6	211.2	213.5	3.8
Sterilised and re-cycled	208.4	211.3	213.6	3.9
SED (44 df)	*0.26*	*0.12*	*0.29*	*0.36*
Significance				
Cultivar (C)	***	***	***	*
Substrate (S)	ns	ns	ns	ns
Usage (U)	ns	***	ns	ns
C x S	***	***	ns	ns
C x U	ns	ns	ns	ns
S x U	ns	**	ns	ns
C x S x U	ns	ns	ns	ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A12. 2002 experiment: Stem lengths and weights: main effect means and significance[1] of effects and interactions. For stem length and overall stem length and weight, the data were analysed after log-transformation, and the back-transformed values are shown in parenthesis

	Length (mm)					*Overall stem weight (g)*		*Stem density (g/cm)*
	Basal stem[2]	*Stem*		*Overall*[3]				
Cultivar								
Brunello	56.9	6.71	(816)	6.93	(1024)	5.03	(152)	0.15
Star Gazer	2.9	6.24	(511)	6.57	(713)	4.23	(69)	0.10
SED (2 df)	*1.77*	*0.008*	-	*0.010*	-	*0.008*	-	*0.001*
Substrate								
1. Peat	22.7	6.45	(631)	6.74	(842)	4.59	(98)	0.12
2. Green/wood 1:3	27.7	6.47	(644)	6.76	(863)	4.70	(110)	0.13
3. Green/wood 1:1	43.5	6.48	(651)	6.74	(846)	4.54	(93)	0.11
4. Wood/bark	25.6	6.49	(657)	6.77	(868)	4.69	(109)	0.13
SED (44 df)	*3.96*	*0.009*	-	*0.008*	-	*0.016*	-	*0.002*
Usage of substrate								
New	38.8	6.47	(648)	6.75	(853)	4.62	(101)	0.12
Re-cycled	28.7	6.47	(645)	6.75	(856)	4.63	(102)	0.12
Sterilised and re-cycled	22.1	6.47	(644)	6.75	(855)	4.64	(103)	0.12
SED (44 df)	*3.43*	*0.008*	-	*0.007*	-	*0.014*	-	*0.002*
Significance								
Cultivar (C)	***	***		***		***		***
Substrate (S)	***	***		***		***		***
Usage (U)	***	ns		ns		ns		ns
C x S	*	**		ns		***		***
C x U	*	ns		*		*		ns
S x U	***	*		***		***		***
C x S x U	**	ns		*		*		*

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability
[2]Basal stem is length of lower stem with yellowing or dead leaves
[3]Length of stem plus inflorescence

Table A13. 2002 experiment: Floret numbers: main effect means and significance[1] of effects and interactions.

	No. viable florets/stem	*No. aborted florets/stem*
Cultivar		
Brunello	5.3	0.3
Star Gazer	2.3	0.2
SED (2 df)	*0.05*	*0.05*
Substrate		
1. Peat	3.8	0.3
2. Green/wood 1:3	3.9	0.2
3. Green/wood 1:1	3.6	0.3
4. Wood/bark	3.8	0.2
SED (44 df)	*0.08*	*0.04*
Usage of substrate		
New	3.7	0.2
Re-cycled	3.8	0.3
Sterilised and re-cycled	3.8	0.3
SED (44 df)	*0.07*	*0.04*
Significance		
Cultivar (C)	***	ns
Substrate (S)	**	ns
Usage (U)	ns	ns
C x S	ns	*
C x U	*	*
S x U	ns	ns
C x S x U	ns	ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A14. 2002 experiment: Foliage colour and lesions: main effect means and significance[1] of effects and interactions. The number of lesions was analysed after log-transformation, and the back-transformed values are shown in parenthesis

	Foliage colour score[2]	*Total number lesions per stem*[3]	
Cultivar			
Brunello	1.26	-0.01	(0.61)
Star Gazer	1.13	-0.45	(0.26)
SED (2 df)	*0.027*	*0.041*	-
Substrate			
1. Peat	1.08	-0.06	(0.57)
2. Green/wood 1:3	1.06	-0.53	(0.22)
3. Green/wood 1:1	1.61	-0.82	(0.07)
4. Wood/bark	1.03	0.48	(1.25)
SED (44 df)	*0.085*	*0.100*	-
Usage of substrate			
New	1.41	-0.20	(0.44)
Re-cycled	1.15	-0.32	(0.35)
Sterilised and re-cycled	1.02	-0.18	(0.46)
SED (44 df)	*0.074*	*0.087*	-
Significance			
Cultivar (C)	*	**	
Substrate (S)	***	***	
Usage (U)	***	ns	
C x S	**	***	
C x U	ns	***	
S x U	***	***	
C x S x U	ns	***	

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A15. 2002 experiment: Foliage lesions and vase-life: main effect means and significance[1] of effects and interactions. Lesion number data were analysed after log-transformation, and the back-transformed values are shown in parenthesis

	Number scorch lesions/stem		*Number* Botrytis *lesions/stem*		*Duration of vase-life (days)*
Cultivar					
Brunello	-0.23	(0.42)	-0.51	(0.23)	10.9
Star Gazer	-0.47	(0.25)	-0.94	(0.02)	13.4
SED (2 df)	*0.057*	-	*0.035*	-	*0.07*
Substrate					
1. Peat	-0.33	(0.35)	-0.37	(0.31)	12.1
2. Green/wood 1:3	-0.55	(0.20)	-0.91	(0.03)	12.0
3. Green/wood 1:1	-0.87	(0.04)	-0.91	(0.03)	12.3
4. Wood/bark	0.36	(1.06)	-0.70	(0.12)	12.1
SED (44 df)	*0.091*	-	*0.057*	-	*0.31*
Usage of substrate					
New	-0.37	(0.32)	-0.54	(0.21)	12.3
Re-cycled	-0.40	(0.29)	-0.81	(0.07)	12.1
Sterilised and re-cycled	-0.27	(0.39)	-0.82	(0.06)	12.0
SED (44 df)	*0.079*	-	*0.049*	-	*0.29*
Significance					
Cultivar (C)	ns		**		***
Substrate (S)	***		***		ns
Usage (U)	ns		***		ns
C x S	***		***		ns
C x U	***		***		ns
S x U	***		***		ns
C x S x U	***		***		ns

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A16. 2001 pot-plant experiment: Marketing date and plant height and width at marketing stage: main effect means and significance[1] of effects and interactions.

Cultivar and treatment		*Marketing date (day no.)*	*Plant height (mm)*	*Plant width (mm)*
Cultivar x substrate				
Memories	1. Peat	237.9	454	205
	2. Green/wood 1:3	236.8	402	189
	3. Green/wood 1:1	237.8	400	183
	4. Wood/bark	324.9	450	195
Butter Pixie	1. Peat	206.2	475	165
	2. Green/wood 1:3	206.4	450	154
	3. Green/wood 1:1	205.9	438	144
	4. Wood/bark	206.2	447	160
SED within cultivar (92 df)		1.00	11.7	4.2
Cultivar x fertiliser				
Memories	Low	239.0	444	201
	Medium	236.3	420	192
	High	235.3	415	186
Butter Pixie	Low	206.6	451	156
	Medium	206.1	456	159
	High	205.8	451	153
SED within cultivar (92 df)		0.86	10.1	3.7
Cultivar x liquid feed				
Memories	None	237.8	417	177
	Yes	236.0	436	209
Butter Pixie	None	206.1	448	148
	Yes	206.3	457	164
SED within cultivar (92 df)		0.70	8.3	3.0
Significance				
Substrate (S)		ns	***	***
Fertiliser (F)		**	ns	**
Liquid feed (LF)		ns	*	***
C x S		ns	*	ns
C x F		ns	ns	*
S x F		ns	*	**
C x LF		ns	ns	***
S x LF		ns	ns	*
F x LF		ns	ns	ns
C x S x F x LF		**	ns	ns
All other second-order interactions		ns	ns	ns
C x S x F x LF		**	ns	*

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

Table A17. 2001 pot-plant experiment: Shelf-life and defects (lesions, basal zone and pale foliage): main effect means and significance[1] of effects and interactions. The number of lesions was analysed after log-transformation, and the percentage of plants with a basal zone (zone of basal yellowing leaves) and pale foliage after arcsin-transformation; the back-transformed values are shown in parenthesis.

Cultivar and treatment		*Shelf-life (days)*	*Lesions per plant*				*% Plants with:*			
			Leaf scorch		Botrytis		*Basal zone*		*Pale foliage*	
Cultivar x substrate										
Memories	1. Peat	18.3	0.38	(1.09)	0.85	(1.95)	25.0	(17.9)	30.0	(25.1)
	2. Green/wood 1:3	16.8	-0.71	(0.12)	-0.83	(0.06)	29.1	(23.7)	45.0	(50.0)
	3. Green/wood 1:1	14.1	-0.91	(0.03)	-0.91	(0.03)	15.0	(6.7)	42.0	(44.7)
	4. Wood/bark	17.2	-0.87	(0.04)	-0.59	(0.18)	20.5	(12.2)	38.7	(39.1)
Butter Pixie	1. Peat	12.1	-0.98	(0)	-0.95	(0.01)	2.0	(0.1)	28.9	(23.4)
	2. Green/wood 1:3	12.9	-0.98	(0)	-0.98	(0)	10.0	(3.0)	21.8	(13.7)
	3. Green/wood 1:1	12.6	-0.95	(0.01)	-0.98	(0)	10.0	(3.0)	0	(0)
	4. Wood/bark	12.7	-0.98	(0)	-0.98	(0)	7.0	(1.5)	3.9	(0.5)
SED within cultivar (92 df)		0.76	0.127	-	0.114	-	7.24	-	8.69	-
Cultivar x fertiliser										
Memories	Low	17.2	-0.47	(0.24)	-0.42	(0.28)	32.0	(28.1)	40.2	(41.6)
	Medium	16.4	-0.66	(0.14)	-0.39	(0.31)	21.2	(13.1)	38.1	(38.1)
	High	16.2	-0.44	(0.27)	-0.31	(0.36)	14.0	(5.8)	38.4	(38.6)
Butter Pixie	Low	13.1	-0.98	(0)	-0.98	(0)	3.8	(0.4)	12.7	(4.9)
	Medium	12.2	-0.98	(0)	-0.98	(0)	2.9	(0.3)	13.4	(5.4)
	High	12.6	-0.95	(0.01)	-0.95	(0.01)	15.0	(6.7)	14.8	(6.6)
SED within cultivar (92 df)		0.65	0.110	-	0.098	-	6.27	-	7.52	-
Cultivar x liquid feed										
Memories	None	16.0	-0.80	(0.08)	-0.66	(0.14)	41.9	(44.6)	74.7	(93.1)
	Yes	17.2	-0.26	(0.40)	-0.08	(0.54)	2.9	(0.3)	3.1	(0.3)
Butter Pixie	None	12.1	-0.98	(0)	-0.98	(0)	6.0	(1.1)	18.9	(10.5)
	Yes	13.1	-0.96	(0.01)	-0.96	(0.01)	8.5	(2.2)	8.4	(2.1)
SED within cultivar (92 df)		0.53	0.090	-	0.080	-	5.12	-	6.14	-
Significance										
Substrate (S)		**	***		***		ns		ns	
Fertiliser (F)		ns	ns		ns		ns		ns	
Liquid feed (LF)		**	***		***		***		***	
C x S		***	***		***		ns		**	
C x F		ns	ns		ns		**		ns	
S x F		ns	ns		ns		ns		ns	
C x LF		ns	***		***		***		***	
S x LF		ns	**		***		*		ns	
F x LF		ns	ns		ns		ns		ns	
C x S x F		ns	ns		ns		ns		ns	
C x S x LF		ns	***		***		ns		ns	
C x F x LF		ns	ns		ns		*		ns	
S x F x LF		ns	ns		ns		ns		ns	
C x S x F x LF		ns	ns		ns		ns		ns	

[1]ns, not significant; *, ** and ***, significant at the 5%, 1% and 0.1% levels of probability

APPENDIX B: SUBSTRATE AND FOLIAGE ANALYSES

Table B1. 2000 experiment. Analysis of substrates after addition of low, medium and high rates of fertiliser

	Peat						Peat + recycled peat						Recycled peat					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	6.1		6.0		5.7		6.1		6.1		5.8		6.0		5.9		5.8	
Conductivity (μS)	146	(0)	232	(1)	349	(2)	212	(1)	345	(2)	391	(2)	250	(1)	366	(2)	466	(3)
Density (g/l)	278		271		293		470		442		447		604		655		629	
Major Nutrients																		
Phosphorus (mg/l)	31	(5)	54	(6)	97	(8)	39	(5)	85	(8)	98	(8)	29	(5)	95	(8)	92	(8)
Potassium (mg/l)	46	(1)	104	(3)	150	(3)	68	(2)	160	(3)	174	(3)	71	(2)	152	(3)	178	(4)
Mg (mg/l)	23	(3)	37	(5)	50	(5)	47	(5)	68	(6)	75	(6)	63	(6)	88	(7)	107	(7)
Mineral nitrogen (mg/l)	50		94		174		59		160		182		56		123		189	
Comprising																		
Nitrate as N (mg/l)	26	(2)	48	(2)	83	(4)	32	(2)	73	(3)	86	(4)	39	(2)	59	(3)	96	(4)
Ammonia as N (mg/l)	24	(1)	46	(1)	91	(2)	27	(1)	87	(2)	96	(2)	17	(0)	64	(2)	93	(2)
Calcium (mg/l)	20		34		46		43		66		69		65		89		104	
Sodium (mg/l)	59		54		50		78		90		70		84		105		89	
Chloride (mg/l)	56		44		47		65		73		67		80		97		102	
Sulphate (mg/l)	52		87		124		93		159		166		113		188		216	
Trace Elements																		
B (mg/l)	0.14		0.18		0.16		0.14		0.18		0.15		0.17		0.19		0.18	
Cu (mg/l)	<0.10		<0.10		<0.10		<0.10		0.12		<0.10		0.10		<0.10		<0.10	
Mn (mg/l)	0.10		0.10		0.10		0.10		0.10		0.10		<0.10		0.10		0.10	
Zn (mg/l)	<0.10		0.20		0.21		0.12		0.21		0.19		0.13		0.28		0.17	
Fe (mg/l)	0.5		<0.5		<0.5		1.1		1.1		0.8		0.9		0.8		1.1	

(continued)

Table B1 (continued). 2000 experiment. Analysis of substrates after addition of low, medium and high rates of fertiliser

	Wood/bark-based						Wood/bark/green compost-based						Green compost/coir-based					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	6.0		5.7		6.3		7.6		7.6		7.5		7.4		7.7		7.8	
Conductivity (μS)	222	(1)	313	(2)	393	(2)	356	(2)	335	(2)	418	(3)	584	(4)	568	(4)	784	(6)
Density (g/l)	399		441		499		486		473		478		503		592		571	
Major Nutrients																		
Phosphorus (mg/l)	30	(5)	73	(7)	70	(7)	45	(6)	69	(7)	102	(9)	284	(9)	200	(9)	358	(9)
Potassium (mg/l)	191	(4)	279	(5)	252	(5)	358	(5)	271	(5)	284	(5)	819	(7)	677	(7)	791	(7)
Mg (mg/l)	7	(1)	19	(3)	16	(3)	13	(2)	10	(1)	12	(2)	17	(3)	13	(2)	17	(3)
Mineral nitrogen (mg/l)	81		138		207		121		129		184		108		135		245	
Comprising																		
Nitrate as N (mg/l)	49	(2)	85	(4)	99	(4)	3	(0)	6	(0)	6	(0)	8	(0)	33	(2)	6	(0)
Ammonia as N (mg/l)	32	(1)	53	(2)	108	(3)	118	(3)	123	(3)	178	(4)	100	(2)	102	(3)	239	(5)
Calcium (mg/l)	23		47		16		50		39		38		70		49		82	
Sodium (mg/l)	84		97		88		70		69		70		178		160		186	
Chloride (mg/l)	112		120		92		203		193		185		430		423		227	
Sulphate (mg/l)	33		66		19		82		56		82		76		59		66	
Trace Elements																		
B (mg/l)	0.33		0.42		0.22		0.42		0.52		0.45		0.62		0.55		0.86	
Cu (mg/l)	0.21		<0.10		<0.10		0.18		0.14		0.13		0.17		0.16		0.24	
Mn (mg/l)	0.40		0.80		<0.10		1.20		0.90		1.00		0.40		0.30		0.70	
Zn (mg/l)	0.28		0.39		0.52		0.56		0.35		0.29		0.40		0.27		0.68	
Fe (mg/l)	1.1		1.3		<0.5		7.7		8.2		9.1		5.9		4.4		10.9	

Table B2 2000 experiment. Analysis of substrates mid-way to cropping, cv Brunello

	Peat			Peat + recycled peat			Recycled peat		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.6	6.3	6.7	6.2	6.1	6.2	6.0	5.9	6.0
Conductivity (μS)	128 (0)	197 (1)	160 (1)	166 (1)	299 (1)	236 (1)	297 (1)	404 (3)	500 (3)
Density (g/l)	286#	312#	314#	382#	416#	408#	503#	511#	542#
<u>Major Nutrients</u>									
Phosphorus (mg/l)	6 (1)	34 (5)	23 (4)	20 (4)	46 (6)	45 (6)	30 (5)	77 (8)	90 (8)
Potassium (mg/l)	39 (1)	72 (2)	75 (2)	49 (1)	92 (2)	109 (3)	84 (2)	126 (3)	204 (4)
Mg (mg/l)	8 (1)	24 (3)	9 (1)	34 (4)	59 (6)	36 (5)	94 (7)	113 (7)	142 (7)
Mineral nitrogen (mg/l)	16	71	53	34	129	84	77	101	180
Comprising									
Nitrate as N (mg/l)	4 (0)	29 (2)	16 (1)	15 (0)	68 (3)	33 (2)	54 (3)	47 (2)	80 (3)
Ammonia as N (mg/l)	12 (0)	42 (1)	37 (1)	19 (0)	61 (2)	51 (2)	23 (1)	54 (2)	100 (2)
Calcium (mg/l)	11	28	15	34	55	38	85	110	147
Sodium (mg/l)	56	58	59	71	74	74	97	95	104
Chloride (mg/l)	33	2	45	68	90	59	120	100	99
Sulphate (mg/l)	26	66	44	64	108	102	139	214	303
<u>Trace Elements</u>									
B (mg/l)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	0.30	0.30	0.20	0.40	0.50	0.40	0.60	0.40	0.50
Fe (mg/l)	0.7	<0.5	0.5	0.6	0.5	1.0	0.7	0.9	0.7

(continued)

Table B2 (continued) 2000 experiment. Analysis of substrates mid-way to cropping, cv Brunello

	Wood/bark-based						Wood/bark/green compost-based						Green compost/coir-based					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	5.9		6.5		6.3		7.4		7.4		7.6		7.2		7.4		7.4	
Conductivity (μS)	184	(1)	204	(1)	215	(1)	140	(0)	145	(0)	157	(1)	264	(1)	289 (1)		267	(1)
Density (g/l)	398#		396#		407#		454#		419#		431#		449#		468#		503#	
<u>Major Nutrients</u>																		
Phosphorus (mg/l)	14	(3)	33	(5)	38	(5)	15	(3)	22	(4)	32	(5)	177	(9)	174	(9)	217	(9)
Potassium (mg/l)	134	(3)	155	(3)	148	(3)	127	(3)	112	(3)	120	(3)	293	(5)	339	(5)	299	(5)
Mg (mg/l)	15	(2)	12	(2)	9	(1)	6	(1)	6	(1)	5	(0)	13	(2)	13	(2)	17	(3)
Mineral nitrogen (mg/l)	32		54		70		16		30		44		29		35		46	
Comprising																		
Nitrate as N (mg/l)	28	(2)	30	(2)	32	(2)	3	(0)	3	(0)	2	(0)	2	(0)	3	(0)	2	(0)
Ammonia as N (mg/l)	4	(0)	24	(1)	38	(1)	13	(0)	27	(1)	42	(1)	27	(1)	32	(1)	44	(1)
Calcium (mg/l)	31		33		21		19		19		17		55		53		74	
Sodium (mg/l)	79		62		71		57		52		50		83		104		85	
Chloride (mg/l)	68		59		57		58		38		36		84		105		58	
Sulphate (mg/l)	56		50		49		25		26		24		31		33		26	
<u>Trace Elements</u>																		
B (mg/l)	0.40		0.30		0.40		0.30		0.30		0.30		0.50		0.50		0.60	
Cu (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		0.10		0.10		<0.10		<0.10	
Mn (mg/l)	<0.10		0.10		0.10		0.20		0.20		0.20		0.30		0.30		0.40	
Zn (mg/l)	0.40		0.30		0.40		0.50		0.30		0.30		0.50		0.50		0.50	
Fe (mg/l)	0.8		0.9		1.1		3.1		2.1		2.7		5.9		6.8		6.7	

determined using 'loose filled' density, not 'compacted bulk density'

Table B3 2000 experiment. Analysis of substrates at cropping (a) cv Brunello

	Peat						Peat + recycled peat						Recycled peat					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	7.0		6.3		6.1		6.5		6.4		5.8		6.5		6.4		6.0	
Conductivity (μS)	151	(1)	237	(1)	361	(2)	278	(1)	301	(2)	471	(3)	227	(1)	155	(1)	278	(1)
Density (g/l)	297		347		342		438		437		415		563		572		557	
<u>Major Nutrients</u>																		
Phosphorus (mg/l)	7	(1)	45	(6)	68	(7)	19	(4)	37	(5)	79	(8)	11	(2)	12	(3)	31	(5)
Potassium (mg/l)	11	(0)	24	(0)	64	(2)	11	(0)	16	(0)	59	(2)	8	(0)	12	(0)	22	(0)
Mg (mg/l)	38	(5)	88	(7)	105	(7)	88	(7)	100	(7)	168	(8)	64	(6)	31	(4)	85	(6)
Mineral nitrogen (mg/l)	7		50		112		4		30		119		<1		2		53	
Comprising																		
Nitrate as N (mg/l)	4	(0)	47	(2)	91	(4)	4	(0)	30	(2)	115	(4)	<1	(0)	2	(0)	53	(3)
Ammonia as N (mg/l)	3	(0)	3	(0)	21	(1)	<1	(0)	<1	(0)	4	(0)	<1	(0)	<1	(0)	<1	(0)
Calcium (mg/l)	35		79		96		89		100		158		71		38		91	
Sodium (mg/l)	75		90		102		111		114		120		104		88		101	
Chloride (mg/l)	76		73		99		114		118		118		102		77		80	
Sulphate (mg/l)	75		122		148		169		161		221		131		74		139	
<u>Trace Elements</u>																		
B (mg/l)	0.42		0.36		0.29		0.31		0.30		0.26		0.34		0.20		0.26	
Cu (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10	
Mn (mg/l)	<0.10		<0.10		0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10	
Zn (mg/l)	0.28		0.43		0.46		0.27		0.29		0.45		0.27		0.23		0.34	
Fe (mg/l)	<0.5		<0.5		<0.5		0.6		0.8		<0.5		0.9		<0.5		<0.5	

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (a) cv Brunello (continued)

	Wood/bark-based						Wood/bark/green compost-based						Green compost/coir-based					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	6.4		6.8		6.2		7.1		7.0		6.9		7.2		7.3		7.2	
Conductivity (μS)	143	(0)	161	(1)	135	(0)	133	(0)	111	(0)	89	(0)	298	(1)	286	(1)	206	(1)
Density (g/l)	410		459		451		473		454		470		544		526		557	
Major Nutrients																		
Phosphorus (mg/l)	5	(1)	13	(3)	15	(3)	9	(2)	9	(2)	8	(2)	164	(9)	97	(8)	79	(8)
Potassium (mg/l)	25	(0)	39	(1)	40	(1)	87	(2)	50	(1)	23	(0)	262	(5)	240	(4)	150	(3)
Mg (mg/l)	15	(2)	18	(3)	13	(2)	7	(1)	6	(1)	6	(1)	21	(3)	17	(3)	14	(2)
Mineral nitrogen (mg/l)	<1		<1		1		1		<1		<1		15		29		52	
Comprising																		
Nitrate as N (mg/l)	<1	(0)	<1	(0)	1	(0)	<1	(0)	<1	(0)	<1	(0)	15	(0)	28	(2)	52	(3)
Ammonia as N (mg/l)	<1	(0)	<1	(0)	<1	(0)	1	(0)	<1	(0)	<1	(0)	<1	(0)	1	(0)	<1	(0)
Calcium (mg/l)	52		59		39		27		22		22		92		72		67	
Sodium (mg/l)	78		80		75		72		71		61		114		111		84	
Chloride (mg/l)	73		78		71		63		62		50		99		137		60	
Sulphate (mg/l)	69		79		59		43		41		33		58		63		29	
Trace Elements																		
B (mg/l)	0.68		0.33		0.44		0.41		0.32		0.22		0.63		0.44		0.36	
Cu (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		0.13		<0.10		<0.10	
Mn (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10	
Zn (mg/l)	0.22		0.22		0.26		0.21		0.18		0.18		0.28		0.23		0.25	
Fe (mg/l)	<0.5		<0.5		<0.5		1.7		0.9		1.0		3.5		2.0		2.5	

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (b) cv Royal Fantasy

	Peat			Peat + recycled peat			Recycled peat		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.5	6.5	6.2	6.5	6.2	6.0	6.3	6.2	5.8
Conductivity (μS)	180 (1)	162 (1)	214 (1)	207 (1)	215 (1)	288 (1)	219 (1)	229 (1)	270 (1)
Density (g/l)	313	384	278	431	448	443	541	580	564
<u>Major Nutrients</u>									
Phosphorus (mg/l)	17 (3)	12 (3)	44 (6)	15 (3)	30 (5)	46 (6)	12 (3)	30 (5)	42 (6)
Potassium (mg/l)	21 (0)	26 (1)	80 (2)	9 (0)	26 (1)	76 (2)	14 (0)	44 (1)	62 (2)
Mg (mg/l)	40 (5)	26 (4)	53 (6)	45 (5)	50 (5)	96 (7)	43 (5)	46 (5)	86 (7)
Mineral nitrogen (mg/l)	5	15	59	4	20	70	6	11	61
Comprising									
Nitrate as N (mg/l)	4 (0)	13 (0)	42 (2)	3 (0)	19 (1)	69 (3)	5 (0)	10 (0)	61 (3)
Ammonia as N (mg/l)	1 (0)	2 (0)	17 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	<1 (0)
Calcium (mg/l)	40	31	50	54	59	95	60	57	92
Sodium (mg/l)	98	109	67	125	112	84	138	132	87
Chloride (mg/l)	107	78	37	112	95	66	124	134	75
Sulphate (mg/l)	80	65	95	105	97	133	105	106	123
<u>Trace Elements</u>									
B (mg/l)	0.31	0.45	0.32	0.33	0.31	0.29	0.42	0.39	0.22
Cu (mg/l)	<0.10	0.12	0.11	0.10	0.10	<0.10	0.13	<0.10	0.10
Mn (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	0.30	0.23	0.87	0.40	0.35	0.83	0.42	0.47	0.77
Fe (mg/l)	<0.5	0.7	<0.5	1.5	1.5	<0.5	1.9	2.1	<0.5

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (b) cv Royal Fantasy (continued)

	Wood/bark-based						Wood/bark/green compost-based						Green compost/coir-based					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	6.0		6.5		6.1		7.4		7.1		7.1		7.3		7.4		7.2	
Conductivity (μS)	221	(1)	178	(1)	169	(1)	157	(1)	80	(0)	99	(0)	306	(2)	172	(1)	254	(1)
Density (g/l)	395		409		438		455		451		455		514		515		590	
Major Nutrients																		
Phosphorus (mg/l)	13	(3)	21	(4)	33	(5)	9	(2)	5	(1)	15	(3)	141	(9)	76	(8)	137	(9)
Potassium (mg/l)	78	(2)	73	(2)	83	(2)	90	(2)	39	(1)	76	(2)	245	(4)	170	(3)	258	(5)
Mg (mg/l)	19	(3)	13	(2)	21	(3)	6	(1)	4	(0)	6	(1)	17	(3)	10	(1)	19	(3)
Mineral nitrogen (mg/l)	4		3		3		5		3		5		11		4		40	
Comprising																		
Nitrate as N (mg/l)	4	(0)	3	(0)	2	(0)	4	(0)	2	(0)	4	(0)	10	(0)	4	(0)	39	(2)
Ammonia as N (mg/l)	<1	(0)	<1	(0)	1	(0)	1	(0)	1	(0)	1	(0)	1	(0)	<1	(0)	1	(0)
Calcium (mg/l)	53		43		59		22		15		20		76		45		83	
Sodium (mg/l)	138		110		72		111		47		57		149		73		90	
Chloride (mg/l)	125		83		55		106		40		43		155		74		61	
Sulphate (mg/l)	100		71		89		47		26		29		54		39		39	
Trace Elements																		
B (mg/l)	0.59		0.40		0.37		0.41		0.21		0.35		0.55		0.33		0.56	
Cu (mg/l)	<0.10		0.20		<0.10		0.22		<0.10		0.10		0.16		<0.10		0.11	
Mn (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		0.10		<0.10		<0.10	
Zn (mg/l)	0.37		0.34		0.79		0.35		0.57		0.65		0.44		0.53		0.77	
Fe (mg/l)	0.8		1.0		<0.5		4.8		0.9		1.3		8.0		2.2		2.5	

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (c) cv Snow Queen

	Peat						Peat + recycled peat						Recycled peat					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	6.7		6.1		6.3		6.3		6.2		6.1		6.3		5.8		5.8	
Conductivity (μS)	92	(0)	249	(1)	117	(0)	152	(1)	218	(1)	288	(1)	180	(1)	317	(2)	341	(2)
Density (g/l)	245		346		280		421		428		457		555		568		546	
<u>Major Nutrients</u>																		
Phosphorus (mg/l)	5	(1)	54	(6)	9	(2)	14	(3)	26	(4)	50	(6)	13	(3)	56	(7)	50	(6)
Potassium (mg/l)	9	(0)	30	(1)	12	(0)	8	(0)	15	(0)	24	(0)	12	(0)	16	(0)	31	(1)
Mg (mg/l)	20	(3)	83	(6)	28	(4)	47	(5)	75	(6)	103	(7)	52	(6)	130	(7)	123	(7)
Mineral nitrogen (mg/l)	2		34		9		2		16		59		3		34		72	
Comprising																		
Nitrate as N (mg/l)	2	(0)	27	(2)	7	(0)	2	(0)	16	(1)	58	(3)	2	(0)	34	(2)	71	(3)
Ammonia as N (mg/l)	<1	(0)	7	(0)	2	(0)	<1	(0)	<1	(0)	1	(0)	1	(0)	<1	(0)	1	(0)
Calcium (mg/l)	22		78		31		49		84		107		59		137		136	
Sodium (mg/l)	54		99		59		71		85		94		87		100		104	
Chloride (mg/l)	40		71		47		64		65		58		83		84		76	
Sulphate (mg/l)	46		139		62		93		135		153		101		197		183	
<u>Trace Elements</u>																		
B (mg/l)	0.26		0.35		0.46		0.19		0.28		0.33		0.32		0.34		0.34	
Cu (mg/l)	<0.10		0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10	
Mn (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10	
Zn (mg/l)	0.66		1.02		0.21		0.87		0.75		0.31		0.68		0.83		0.30	
Fe (mg/l)	<0.5		<0.5		<0.5		<0.5		0.6		0.7		0.9		0.7		0.8	

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (c) cv Snow Queen (continued)

	Wood/bark-based						Wood/bark/green compost-based						Green compost/coir-based					
	Low		Medium		High		Low		Medium		High		Low		Medium		High	
pH	6.2		6.5		6.3		7.2		7.3		6.9		7.2		7.3		7.2	
Conductivity (μS)	120	(0)	114	(0)	163	(1)	103	(0)	98	(0)	108	(0)	257	(1)	226	(1)	246	(1)
Density (g/l)	416		412		442		468		456		481		492		482		573	
<u>Major Nutrients</u>																		
Phosphorus (mg/l)	6	(1)	12	(3)	23	(4)	6	(1)	8	(2)	17	(3)	133	(9)	96	(8)	162	(9)
Potassium (mg/l)	34	(1)	25	(0)	48	(1)	30	(1)	33	(1)	38	(1)	220	(4)	186	(4)	166	(3)
Mg (mg/l)	14	(2)	13	(2)	22	(3)	10	(1)	10	(1)	10	(1)	22	(3)	18	(3)	25	(3)
Mineral nitrogen (mg/l)	3		3		3		3		3		3		3		4		17	
Comprising																		
Nitrate as N (mg/l)	2	(0)	2	(0)	3	(0)	2	(0)	2	(0)	2	(0)	2	(0)	3	(0)	16	(1)
Ammonia as N (mg/l)	1	(0)	1	(0)	<1	(0)	1	(0)	1	(0)	1	(0)	1	(0)	1	(0)	1	(0)
Calcium (mg/l)	37		41		70		39		37		37		98		77		127	
Sodium (mg/l)	73		66		76		64		59		65		111		106		89	
Chloride (mg/l)	63		54		60		51		44		47		110		93		73	
Sulphate (mg/l)	61		47		90		38		32		39		69		62		51	
<u>Trace Elements</u>																		
B (mg/l)	0.62		0.41		0.44		0.35		0.36		0.37		0.54		0.49		0.61	
Cu (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		0.11		<0.10		<0.10	
Mn (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		<0.10		0.10	
Zn (mg/l)	0.60		0.58		0.21		0.67		0.58		0.22		0.75		0.72		0.26	
Fe (mg/l)	0.5		0.5		0.5		1.6		1.6		2.0		3.0		2.6		4.4	

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (d) cv Star Gazer

	Peat			Peat + recycled peat			Recycled peat		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.4	6.6	6.4	6.4	6.1	5.9	6.5	6.3	5.9
Conductivity (μS)	156 (1)	158 (1)	235 (1)	155 (1)	273 (1)	442 (3)	115 (0)	171 (1)	261 (1)
Density (g/l)	333	326	335	448	463	480	581	611	580
<u>Major Nutrients</u>									
Phosphorus (mg/l)	19 (4)	21 (4)	49 (6)	16 (3)	33 (5)	76 (8)	9 (2)	23 (4)	42 (6)
Potassium (mg/l)	17 (0)	54 (2)	103 (3)	17 (0)	54 (2)	125 (3)	27 (1)	36 (1)	74 (2)
Mg (mg/l)	46 (5)	18 (3)	25 (3)	47 (5)	81 (6)	142 (7)	25 (3)	39 (5)	87 (7)
Mineral nitrogen (mg/l)	19	43	93	4	33	119	2	12	60
Comprising									
Nitrate as N (mg/l)	17 (1)	24 (1)	44 (2)	4 (0)	32 (2)	113 (4)	2 (0)	12 (0)	59 (3)
Ammonia as N (mg/l)	2 (0)	19 (0)	49 (1)	<1 (0)	1 (0)	6 (0)	<1 (0)	<1 (0)	1 (0)
Calcium (mg/l)	42	21	27	49	83	141	31	51	94
Sodium (mg/l)	66	85	84	66	109	121	65	87	83
Chloride (mg/l)	65	66	72	78	109	111	69	75	69
Sulphate (mg/l)	70	48	76	84	137	191	52	80	132
<u>Trace Elements</u>									
B (mg/l)	0.30	0.30	0.30	0.26	0.28	0.27	0.29	0.30	0.29
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	0.13	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	0.25	0.22	0.31	0.22	0.38	0.43	0.22	0.30	0.39
Fe (mg/l)	<0.5	<0.5	<0.5	0.6	1.0	0.5	1.3	1.5	1.0

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (d) cv Star Gazer (continued)

	Wood/bark-based			Wood/bark/green compost-based			Green compost/coir-based		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.1	6.5	6.2	7.5	7.2	7.3	7.2	7.3	7.3
Conductivity (μS)	132 (0)	161 (1)	173 (1)	103 (0)	105 (0)	106 (0)	302 (2)	270 (1)	255 (1)
Density (g/l)	429	396	403	492	472	472	527	524	560
<u>Major Nutrients</u>									
Phosphorus (mg/l)	8 (2)	32 (5)	39 (5)	6 (1)	10 (2)	22 (4)	190 (9)	161 (9)	180 (9)
Potassium (mg/l)	66 (2)	120 (3)	118 (3)	48 (1)	61 (2)	102 (3)	274 (5)	247 (4)	216 (4)
Mg (mg/l)	11 (2)	13 (2)	19 (3)	6 (1)	6 (1)	6 (1)	22 (3)	19 (3)	28 (4)
Mineral nitrogen (mg/l)	2	3	5	4	5	5	7	9	25
Comprising									
Nitrate as N (mg/l)	2 (0)	3 (0)	5 (0)	3 (0)	4 (0)	4 (0)	6 (0)	8 (0)	25 (1)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	<1 (0)
Calcium (mg/l)	29	39	53	22	22	21	97	85	133
Sodium (mg/l)	75	71	81	76	69	63	126	108	98
Chloride (mg/l)	74	74	73	61	75	50	125	104	54
Sulphate (mg/l)	62	64	85	26	29	22	55	50	50
<u>Trace Elements</u>									
B (mg/l)	0.52	0.40	0.47	0.39	0.35	0.35	0.71	0.51	0.65
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.16	0.12	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	0.10	0.10
Zn (mg/l)	0.28	0.23	0.41	0.21	0.18	0.31	0.42	0.28	0.39
Fe (mg/l)	<0.5	0.9	0.7	2.4	2.8	2.9	5.6	4.4	3.3

(continued)

Table B3 (continued) 2000 experiment. Analysis of substrates at cropping (d) cv Elite (medium fertiliser rate only)

	Medium fertiliser rate											
	Peat		Peat + recycled peat		Recycled peat		Wood/bark-based		Wood/bark/green compost-based		Green compost/coir-based	
pH	6.5		7.3		7.4		6.2		6.3		6.1	
Conductivity (μS)	165	(1)	110	(0)	279	(1)	242	(1)	190	(1)	330	(2)
Density (g/l)	454		518		532		349		333		474	
Major Nutrients												
Phosphorus (mg/l)	21	(4)	9	(2)	126	(9)	46	(6)	28	(4)	37	(5)
Potassium (mg/l)	83	(2)	76	(2)	330	(5)	27	(1)	43	(1)	70	(2)
Mg (mg/l)	20	(3)	9	(1)	16	(3)	90	(7)	57	(6)	124	(7)
Mineral nitrogen (mg/l)	2		3		6		50		48		55	
Comprising												
Nitrate as N (mg/l)	2	(0)	2	(0)	5	(0)	47	(2)	40	(2)	54	(3)
Ammonia as N (mg/l)	<1	(0)	1	(0)	1	(0)	3	(0)	8	(0)	1	(0)
Calcium (mg/l)	60		29		70		83		48		118	
Sodium (mg/l)	90		72		122		92		79		108	
Chloride (mg/l)	78		64		162		75		68		119	
Sulphate (mg/l)	89		37		54		124		83		191	
Trace Elements												
B (mg/l)	0.41		0.36		0.51		0.38		0.35		0.23	
Cu (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10	
Mn (mg/l)	<0.10		<0.10		<0.10		<0.10		<0.10		<0.10	
Zn (mg/l)	0.35		0.32		0.36		0.35		0.35		0.40	
Fe (mg/l)	0.7		2.5		2.8		<0.5		<0.5		<0.5	

Table B4 2000 experiment. Analysis of foliage at cropping time (a) cv Brunello

	Peat			Peat + recycled peat			Recycled peat		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	8.6	8.5	8.3	7.7	8.7	7.9	8.1	7.7	7.9
N (% m/m)	3.36	3.88	4.32	3.32	3.69	4.08	3.40	3.85	3.91
Total Ca (% m/m)	0.91	0.71	0.78	0.85	0.88	0.79	0.89	0.81	0.82
Total K (% m/m)	3.31	4.21	4.82	4.07	4.78	5.20	3.81	4.49	4.94
Total Mg (% m/m)	0.85	0.60	0.56	0.71	0.65	0.59	0.67	0.60	0.58
Total P (% m/m)	0.34	0.41	0.39	0.29	0.30	0.34	0.26	0.34	0.30
Total Mn (mg/kg)	54.5	52.3	57.8	36.1	44.1	47.3	31.8	36.3	39.8

	Wood/bark-based			Wood/bark/green compost-based			Green compost/coir-based		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	7.8	8.4	7.7	7.8	7.4	7.7	7.5	7.0	7.1
N (% m/m)	2.77	3.43	4.02	3.54	3.77	4.19	4.01	3.84	4.15
Total Ca (% m/m)	1.07	1.02	1.18	0.68	0.82	0.76	0.67	0.64	0.59
Total K (% m/m)	4.58	4.59	5.05	5.64	5.05	4.94	5.60	5.61	5.87
Total Mg (% m/m)	0.40	0.33	0.33	0.24	0.28	0.29	0.23	0.19	0.20
Total P (% m/m)	0.25	0.33	0.37	0.25	0.31	0.33	0.33	0.32	0.34
Total Mn (mg/kg)	65.7	160	151	102	161	171	46.8	42.0	40.1

(continued)

Table B4 (continued) 2000 experiment. Analysis of foliage at cropping time (b) cv Royal Fantasy

	Peat			Peat + recycled peat			Recycled peat		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	9.4	10.6	10.9	9.9	9.4	10.3	9.4	10.0	9.6
N (% m/m)	3.73	4.24	5.01	3.34	4.18	4.35	3.52	4.11	4.16
Total Ca (% m/m)	0.90	0.97	0.97	0.98	1.03	0.99	1.15	1.06	1.09
Total K (% m/m)	2.97	3.65	4.00	3.34	4.58	4.35	3.51	4.35	4.72
Total Mg (% m/m)	0.94	0.88	0.78	0.89	0.83	0.80	0.95	0.81	0.79
Total P (% m/m)	0.39	0.39	0.46	0.25	0.30	0.32	0.25	0.31	0.33
Total Mn (mg/kg)	77.6	104	98.2	40.1	54.3	58.8	43.7	53.8	71.3

	Wood/bark-based			Wood/bark/green compost-based			Green compost/coir-based		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	10.1	9.6	9.4	10.6	9.6	8.7	9.9	10.0	9.0
N (% m/m)	3.12	3.96	4.19	2.81	3.68	4.02	3.49	3.95	3.98
Total Ca (% m/m)	1.08	1.10	1.05	1.79	1.13	1.10	1.04	1.00	1.15
Total K (% m/m)	4.82	5.30	5.48	4.00	4.90	4.86	5.68	5.53	5.01
Total Mg (% m/m)	0.42	0.43	0.34	0.46	0.37	0.35	0.27	0.26	0.30
Total P (% m/m)	0.28	0.34	0.37	0.20	0.25	0.29	0.26	0.28	0.27
Total Mn (mg/kg)	74.2	137	131	150	180	180	70.7	69.3	72.5

(continued)

Table B4 (continued) 2000 experiment. Analysis of foliage at cropping time (c) cv Snow Queen

	Peat			Peat + recycled peat			Recycled peat		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	9.2	10.2	9.1	8.4	8.6	9.4	10.1	10.0	9.4
N (% m/m)	2.86	3.26	3.28	2.65	3.03	3.23	2.76	3.17	3.26
Total Ca (% m/m)	1.25	1.15	1.17	1.10	1.29	1.21	1.16	1.14	1.18
Total K (% m/m)	3.06	5.23	4.84	4.01	5.17	5.50	3.77	5.25	5.50
Total Mg (% m/m)	1.00	0.79	0.74	0.72	0.87	0.78	0.76	0.73	0.73
Total P (% m/m)	0.24	0.28	0.29	0.24	0.23	0.24	0.22	0.25	0.25
Total Mn (mg/kg)	59.3	69.2	66.5	45.6	46.6	48.0	36.1	41.5	42.3

	Wood/bark-based			Wood/bark/green compost-based			Green compost/coir-based		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	11.3	10.8	9.1	11.2	9.7	10.1	8.9	8.9	7.8
N (% m/m)	2.63	2.67	3.05	1.63	2.33	2.86	2.34	2.44	2.89
Total Ca (% m/m)	1.12	1.44	1.42	0.95	1.03	1.06	0.88	1.03	1.18
Total K (% m/m)	5.50	4.61	6.17	5.67	5.73	5.08	6.91	7.16	7.80
Total Mg (% m/m)	0.38	0.38	0.34	0.18	0.25	0.38	0.21	0.19	0.25
Total P (% m/m)	0.22	0.22	0.26	0.14	0.18	0.22	0.21	0.21	0.22
Total Mn (mg/kg)	52.7	57.6	109	67.1	123	134	38.2	34.2	51.9

(continued)

Table B4 (continued) 2000 experiment. Analysis of foliage at cropping time (d) cv Star Gazer

	Peat			Peat + recycled peat			Recycled peat		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	9.9	11.0	11.1	12.3	11.5	11.0	12.1	11.1	11.0
N (% m/m)	3.50	3.97	4.50	3.25	3.57	3.84	3.25	3.64	4.07
Total Ca (% m/m)	1.09	1.19	1.17	1.39	1.33	1.37	1.28	1.51	1.12
Total K (% m/m)	3.80	4.10	4.06	3.46	3.80	4.01	3.44	4.51	3.45
Total Mg (% m/m)	0.89	0.90	0.81	0.99	0.91	0.92	0.90	0.99	0.72
Total P (% m/m)	0.25	0.26	0.32	0.21	0.24	0.26	0.19	0.28	0.23
Total Mn (mg/kg)	57.5	69.5	66.7	38.5	40.9	46.9	30.8	46.1	39.3

	Wood/bark-based			Wood/bark/green compost-based			Green compost/coir-based		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
ODM (% m/m)	11.1	10.5	11.1	11.2	10.4	10.8	10.6	11.0	11.9
N (% m/m)	3.17	3.68	3.69	2.65	3.64	3.80	3.58	3.59	3.38
Total Ca (% m/m)	1.66	1.80	1.70	1.18	1.12	1.30	1.09	1.17	1.19
Total K (% m/m)	4.47	4.38	4.50	4.93	5.10	4.45	4.01	4.64	4.32
Total Mg (% m/m)	0.51	0.45	0.42	0.26	0.30	0.44	0.52	0.22	0.23
Total P (% m/m)	0.19	0.22	0.23	0.14	0.19	0.22	0.23	0.21	0.18
Total Mn (mg/kg)	74.2	142	129	109	161	165	54.3	51.4	44.9

(continued)

Table B4 (continued) 2000 experiment. Analysis of foliage at cropping time (e) cv Elite (medium fertiliser rate only)

	Medium fertiliser rate					
	Peat	Peat + recycled peat	Recycled peat	Wood/bark-based	Wood/bark/green compost-based	Green compost/coir-based
ODM (% m/m)	10.7	10.0	9.4	9.1	9.5	9.6
N (% m/m)	4.55	4.26	4.13	4.05	3.62	4.04
Total Ca (% m/m)	1.23	1.31	1.27	1.50	1.26	1.23
Total K (% m/m)	2.87	2.80	3.65	4.07	4.12	4.38
Total Mg (% m/m)	0.85	0.91	0.81	0.36	0.34	0.23
Total P (% m/m)	0.43	0.41	0.40	0.40	0.32	0.35
Total Mn (mg/kg)	77.4	60.9	40.8	159	190	43.8

Table B5 2001 Analysis of substrates after addition of low, medium and high rates of fertiliser. Water extraction.

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.3	6.1	5.9	7.1	7.0	6.9	7.7	7.8	7.7
Conductivity (μS)	95 (0)	151 (1)	246 (1)	214 (1)	361 (2)	389 (2)	219 (1)	246 (1)	258 (1)
	215	230	275	439	405	394	415	479	426
Major Nutrients									
Phosphorus (mg/l)	16 (3)	41 (6)	73 (7)	35 (5)	47 (6)	60 (7)	20 (4)	34 (5)	48 (6)
Potassium (mg/l)	19 (0)	54 (2)	125 (3)	265 (5)	299 (5)	298 (5)	293 (5)	342 (5)	314 (5)
Mg (mg/l)	12 (2)	23 (3)	38 (5)	8 (1)	9 (1)	9 (1)	6 (1)	6 (1)	6 (1)
Mineral nitrogen (mg/l)	21	60	109	15	212	258	3	9	50
Comprising									
Nitrate as N (mg/l)	10 (0)	30 (2)	58 (3)	7 (0)	118 (4)	144 (5)	2 (0)	2 (0)	14 (0)
Ammonia as N (mg/l)	11 (0)	30 (1)	51 (2)	8 (0)	94 (2)	114 (3)	1 (0)	7 (0)	36 (1)
Calcium (mg/l)	12	19	30	35	54	48	34	34	35
Sodium (mg/l)	51	54	57	74	72	63	67	79	64
Chloride (mg/l)	43	45	48	160	143	128	170	205	202
Sulphate (mg/l)	30	55	96	15	11	11	11	11	10
Trace Elements									
B (mg/l)	0.19	0.19	0.21	0.52	0.49	0.49	0.47	0.54	0.51
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	>0.10
Mn (mg/l)	<0.10	0.10	0.10	0.30	0.50	0.70	0.20	0.10	0.30
Zn (mg/l)	0.26	0.31	0.35	0.34	0.29	0.32	0.28	0.36	0.22
Fe (mg/l)	<0.5	<0.5	<0.5	2.3	1.8	1.4	2.0	1.9	1.9

(continued)

Table B5 (continued) Analysis of substrates after addition of low, medium and high rates of fertiliser Water extraction.

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	6.2	6.3	6.1
Conductivity (μS)	208 (1)	234 (1)	265 (1)
Density (g/l)	351	362	361
<u>Major Nutrients</u>			
Phosphorus (mg/l)	52 (6)	65 (7)	78 (8)
Potassium (mg/l)	201 (4)	204 (4)	216 (4)
Mg (mg/l)	5 (0)	5 (0)	7 (1)
Mineral nitrogen (mg/l)	115	160	168
Comprising			
Nitrate as N (mg/l)	73 (3)	96 (4)	97 (4)
Ammonia as N (mg/l)	42 (1)	64 (2)	71 (2)
Calcium (mg/l)	16	18	23
Sodium (mg/l)	44	43	56
Chloride (mg/l)	73	65	73
Sulphate (mg/l)	12	10	24
<u>Trace Elements</u>			
B (mg/l)	0.37	0.35	0.32
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	0.40	0.60	0.60
Zn (mg/l)	0.46	0.45	0.47
Fe (mg/l)	1.1	0.9	1.0

Table B6 2001 Analysis of substrates after addition of low, medium and high rates of fertiliser. DTPA extraction.

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	3.9	4.0	3.9	4.6	4.4	4.1	4.8	5.1	5.2
Conductivity (µS)	2210	2260	2340	2340	2390	2420	2240	2250	2290
Major Nutrients									
Phosphorus (mg/l)	17	44	82	76	102	76	72	99	99
Potassium (mg/l)	32	85	158	431	451	409	513	581	525
Magnesium (mg/l)	370	353	380	119	111	87	119	131	118
Nitrate as N (mg/l)	22	43	70	115	116	134	14	14	36
Ammonia as N (mg/l)	22	42	80	124	143	158	5	11	54
Sodium (mg/l)	28	29	34	47	49	44	65	75	64
Sulphur (mg/l)	26.3	5.4	87.6	14.0	11.5	7.1	9.6	10.2	9.1
Trace Elements									
Boron (mg/l)	0.24	0.23	0.31	0.77	0.73	0.61	0.90	1.02	0.88
Copper (mg/l)	<0.50	<0.50	<0.50	0.70	0.75	0.50	1.16	1.29	1.07
Manganese (mg/l)	2.77	2.83	3.40	33.7	38.8	32.6	29.5	27.6	32.8
Zinc (mg/l)	2.40	2.30	2.98	12.4	12.7	9.30	14.8	17.4	15.2
Iron (mg/l)	16.3	16.2	18.4	86.4	85.4	44.5	100	107	82.1

(continued)

Table B6 (continued) Analysis of substrates after addition of low, medium and high rates of fertiliser DTPA extraction.

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.6	3.5	3.6
Conductivity (µS)	2340	2400	2450
<u>Major Nutrients</u>			
Phosphorus (mg/l)	56	69	97
Potassium (mg/l)	346	335	357
Magnesium (mg/l)	111	100	102
Nitrate as N (mg/l)	79	101	125
Ammonia as N (mg/l)	68	105	125
Sodium (mg/l)	26	25	25
Sulphur (mg/l)	7.7	5.4	20.5
<u>Trace Elements</u>			
Boron (mg/l)	0.58	0.56	0.50
Copper (mg/l)	<0.50	<0.50	<0.50
Manganese (mg/l)	47.7	50.5	42.9
Zinc (mg/l)	8.60	8.67	7.40
Iron (mg/l)	41.6	37.5	34.6

Table B7 2001 Analysis of substrates after cropping, water extraction (a) cv Brunello, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.3	6.0	5.7	7.0	7.0	6.8	7.7	7.7	7.6
Conductivity (μS)	193 (1)	159 (1)	311 (2)	178 (1)	171 (1)	201 (1)	157 (1)	149 (0)	153 (1)
Density (g/l)	396	328	309	488	461	458	479	521	500
<u>Major Nutrients</u>									
Phosphorus (mg/l)	7 (1)	16 (30	79 (8)	14 (3)	18 (3)	30 (5)	9 (2)	14 (3)	12 (3)
Potassium (mg/l)	24 (0)	15 (0)	48 (1)	84 (2)	83 (2)	81 (2)	114 (3)	111 (3)	82 (2)
Mg (mg/l)	54 (6)	48 (5)	114 (7)	13 (2)	13 (2)	15 (2)	8 (1)	8 (1)	10 (1)
Mineral nitrogen (mg/l)	9	11	67	5	5	4	5	5	4
Comprising									
Nitrate as N (mg/l)	7 (0)	10 (0)	53 (3)	5 (0)	5 (0)	4 (0)	5 (0)	5 (0)	4 (0)
Ammonia as N (mg/l)	2 (0)	1 (0)	14 (0)	<1 (0)	<1 (0)	<1(0)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	44	39	89	69	75	78	44	47	58
Sodium (mg/l)	94	76	93	91	87	86	80	77	77
Chloride (mg/l)	115	88	79	106	97	103	101	91	89
Sulphate (mg/l)	102	83	165	75	76	71	55	52	65
<u>Trace Elements</u>									
B (mg/l)	0.38	0.45	0.58	0.45	0.47	0.49	0.37	0.38	0.37
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	0.40	<0.10	<0.10	<0.10	<0.10	0.10	<0.10
Zn (mg/l)	<0.10	0.29	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	0.6	0.6	0.6	0.7	2.1	0.9

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Brunello, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	5.9	5.6	5.7
Conductivity (μS)	141 (0)	132 (0)	132 (0)
Density (g/l)	413	409	411
Major Nutrients			
Phosphorus (mg/l)	9 (2)	17 (3)	26 (4)
Potassium (mg/l)	46 (1)	43 (1)	53 (2)
Mg (mg/l)	15 (2)	13 (2)	14 (2)
Mineral nitrogen (mg/l)	4	5	5
Comprising			
Nitrate as N (mg/l)	4 (0)	5 (0)	5 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	53	49	51
Sodium (mg/l)	76	83	70
Chloride (mg/l)	78	71	68
Sulphate (mg/l)	74	63	64
Trace Elements			
B (mg/l)	1.15	0.84	0.77
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	<0.10
Zn (mg/l)	0.10	0.12	0.11
Fe (mg/l)	<0.5	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Brunello, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	5.9	5.7	5.5	7.0	6.8	6.9	7.8	7.6	7.4
Conductivity (μS)	242 (1)	305 (2)	336 (2)	153 (1)	159 (1)	156 (1)	138 (0)	134 (0)	152 (1)
Density (g/l)	317	343	354	476	461	458	504	513	493
Major Nutrients									
Phosphorus (mg/l)	17 (3)	38 (5)	60 (7)	14 (3)	20 (4)	25 (4)	10 (2)	15 (3)	17 (3)
Potassium (mg/l)	42 (1)	57 (2)	98 (2)	120 (3)	117 (3)	117 (3)	126 (3)	134 (3)	124 (3)
Mg (mg/l)	81 (6)	109 (7)	110 (7)	6 (1)	8 (1)	8 (1)	4 (0)	5 (0)	6 (1)
Mineral nitrogen (mg/l)	74	98	122	8	9	7	6	6	6
Comprising									
Nitrate as N (mg/l)	74 (3)	98 (4)	121 (4)	8 (0)	9 (0)	6 (0)	6 (0)	6 (0)	6 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	1 (0)	<1 (0)	<1 (0)	1 (0)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	65	83	96	33	51	48	29	29	41
Sodium (mg/l)	77	92	86	75	75	80	69	65	78
Chloride (mg/l)	90	95	71	86	88	89	79	81	88
Sulphate (mg/l)	90	113	109	50	56	52	36	31	46
Trace Elements									
B (mg/l)	0.30	0.52	0.50	0.38	0.38	0.42	0.32	0.34	0.38
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	0.48	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	0.12	0.12	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	0.5	0.6	1.0	0.6	0.8	<0.5

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Brunello, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	5.7	5.8	5.6
Conductivity (μS)	220 (1)	150 (0)	243 (1)
Density (g/l)	425	430	416
Major Nutrients			
Phosphorus (mg/l)	18 (3)	23 (4)	35 (5)
Potassium (mg/l)	115 (3)	95 (2)	124 (3)
Mg (mg/l)	22 (3)	14 (2)	27 (4)
Mineral nitrogen (mg/l)	47	25	73
Comprising			
Nitrate as N (mg/l)	47 (2)	23 (1)	73 (3)
Ammonia as N (mg/l)	<1 (0)	2 (0)	<1 (0)
Calcium (mg/l)	86	53	105
Sodium (mg/l)	87	52	76
Chloride (mg/l)	90	63	73
Sulphate (mg/l)	85	56	78
Trace Elements			
B (mg/l)	0.88	0.74	0.77
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	0.10	<0.10	0.10
Zn (mg/l)	0.17	<0.10	0.12
Fe (mg/l)	<0.5	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Royal Fantasy, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.3	5.9	5.8	7.4	7.2	7.1	8.0	7.9	7.9
Conductivity (μS)	154 (1)	260 (1)	324 (2)	164 (1)	127 (0)	146 (0)	163 (1)	156 (1)	158 (1)
Density (g/l)	344	352	359	486	487	441	483	510	509
Major Nutrients									
Phosphorus (mg/l)	15 (3)	45 (6)	113 (9)	16 (3)	17 (3)	24 (4)	13 (3)	15 (3)	19 (4)
Potassium (mg/l)	10 (0)	40 (1)	98 (2)	166 (3)	118 (3)	128 (3)	183 (4)	159 (3)	177 (4)
Mg (mg/l)	48 (5)	99 (7)	121 (7)	6 (1)	4 (0)	6 (1)	4 (0)	5 (0)	6 (1)
Mineral nitrogen (mg/l)	5	23	70	6	5	4	4	6	5
Comprising									
Nitrate as N (mg/l)	5 (0)	23 (1)	61 (3)	6 (0)	5 (0)	4 (0)	4 (0)	5 (0)	5 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	9 (0)	<1 (0)	<1 (0)	<1 (0)	<1 (0)	1 (0)	<1 (0)
Calcium (mg/l)	38	73	88	31	21	35	23	27	29
Sodium (mg/l)	82	100	92	78	62	69	72	69	69
Chloride (mg/l)	80	98	61	103	81	93	110	97	96
Sulphate (mg/l)	90	156	163	47	35	41	35	39	28
Trace Elements									
B (mg/l)	0.30	0.47	0.58	0.45	0.37	0.40	0.38	0.37	0.39
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	0.31	0.18	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	0.8	0.6	0.7	1.1	0.9	1.5

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Royal Fantasy, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	5.8	5.8	5.8
Conductivity (μS)	161 (1)	153 (1)	142 (0)
Density (g/l)	394	409	400
Major Nutrients			
Phosphorus (mg/l)	17 (3)	28 (4)	40 (5)
Potassium (mg/l)	80 (2)	80 (2)	110 (3)
Mg (mg/l)	13 (2)	11 (2)	9 (1)
Mineral nitrogen (mg/l)	6	10	8
Comprising			
Nitrate as N (mg/l)	5 (0)	4 (0)	5 (0)
Ammonia as N (mg/l)	1 (0)	6 (0)	3 (0)
Calcium (mg/l)	46	41	34
Sodium (mg/l)	82	81	70
Chloride (mg/l)	97	85	71
Sulphate (mg/l)	72	64	58
Trace Elements			
B (mg/l)	1.40	1.59	1.16
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	0.10	0.80	0.10
Zn (mg/l)	0.14	0.19	0.12
Fe (mg/l)	<0.5	0.9	0.7

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Royal Fantasy, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	5.9	5.6	5.5	7.4	7.4	7.1	7.9	7.8	7.8
Conductivity (μS)	267 (1)	246 (1)	330 (2)	164 (1)	163 (1)	157 (1)	170 (1)	184 (1)	174 (1)
Density (g/l)	337	327	335	492	464	462	518	529	544
Major Nutrients									
Phosphorus (mg/l)	26 (4)	35 (5)	71 (7)	18 (3)	21 (4)	31 (5)	17 (3)	22 (4)	27 (4)
Potassium (mg/l)	43 (1)	68 (2)	129 (3)	194 (4)	171 (3)	180 (4)	234 (4)	237 (4)	216 (4)
Mg (mg/l)	82 (6)	75 (6)	104 (7)	4 (0)	6 (1)	6 (1)	4 (0)	5 (0)	5 (0)
Mineral nitrogen (mg/l)	54	61	110	9	6	11	7	13	8
Comprising									
Nitrate as N (mg/l)	54 (3)	61 (3)	108 (4)	8 (0)	6 (0)	11 (0)	6 (0)	13 (0)	8 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	2 (0)	1 (0)	<1 (0)	<1 (0)	1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	61	58	85	24	40	38	24	31	32
Sodium (mg/l)	93	85	84	69	74	70	74	76	78
Chloride (mg/l)	113	75	69	89	81	81	94	99	96
Sulphate (mg/l)	115	101	122	31	34	34	24	30	25
Trace Elements									
B (mg/l)	0.32	0.42	0.54	0.39	0.39	0.41	0.38	0.40	0.44
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	0.40	<0.10	<0.10	<0.10	<0.10	<0.10	0.10
Zn (mg/l)	<0.10	<0.10	0.14	<0.10	<0.10	<0.10	<0.10	<0.10	0.11
Fe (mg/l)	<0.5	<0.5	<0.5	1.1	0.8	0.8	1.7	1.4	2.5

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Royal Fantasy, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	6.0	5.8	5.6
Conductivity (μS)	125 (0)	147 (0)	188 (1)
Density (g/l)	386	439	404
Major Nutrients			
Phosphorus (mg/l)	17 (3)	33 (5)	36 (5)
Potassium (mg/l)	123 (3)	136 (3)	169 (3)
Mg (mg/l)	4 (0)	9 (1)	13 (2)
Mineral nitrogen (mg/l)	7	23	59
Comprising			
Nitrate as N (mg/l)	7 (0)	23 (1)	59 (3)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	16	30	52
Sodium (mg/l)	66	71	65
Chloride (mg/l)	69	65	60
Sulphate (mg/l)	47	46	44
Trace Elements			
B (mg/l)	0.80	0.65	0.75
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	0.10
Zn (mg/l)	<0.10	<0.10	0.10
Fe (mg/l)	<0.5	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Snow Queen, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.3	5.9	5.9	7.4	7.0	7.0	7.5	7.5	7.4
Conductivity (μS)	227 (1)	261 (1)	253 (1)	146 (0)	133 (0)	143 (0)	154 (1)	152 (1)	149 (0)
Density (g/l)	422	333	306	497	487	466	488	510	544
<u>Major Nutrients</u>									
Phosphorus (mg/l)	18 (3)	47 (6)	52 (6)	15 (3)	18 (3)	26 (4)	11 (2)	16 (3)	17 (3)
Potassium (mg/l)	12 (0)	16 (0)	28 (1)	111 (3)	60 (2)	87 (2)	120 (3)	101 (3)	115 (3)
Mg (mg/l)	71 (6)	97 (7)	88 (7)	7 (1)	14 (2)	8 (1)	8 (1)	7 (1)	9 (1)
Mineral nitrogen (mg/l)	16	29	57	6	11	5	5	5	5
Comprising									
Nitrate as N (mg/l)	16 (1)	28 (2)	51 (3)	6 (0)	11 (0)	5 (0)	5 (0)	5 (0)	5 (0)
Ammonia as N (mg/l)	<1 (0)	1 (0)	6 (0)	<1 (0)	<1 (0)	<1 (0)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	57	80	74	39	49	45	44	41	49
Sodium (mg/l)	120	93	78	66	66	69	63	72	64
Chloride (mg/l)	100	67	52	79	67	69	73	82	84
Sulphate (mg/l)	133	164	129	41	54	47	57	45	51
<u>Trace Elements</u>									
B (mg/l)	0.38	0.50	0.49	0.39	0.42	0.45	0.32	0.34	0.35
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.30	0.20	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	1.0	<0.5	0.6	<0.5	0.7	0.6

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Snow Queen, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	5.6	5.6	5.6
Conductivity (μS)	144 (0)	132 (0)	157 (1)
Density (g/l)	411	421	442
Major Nutrients			
Phosphorus (mg/l)	21 (4)	26 (4)	33 (5)
Potassium (mg/l)	60 (2)	51 (2)	84 (2)
Mg (mg/l)	17 (3)	13 (2)	16 (3)
Mineral nitrogen (mg/l)	5	5	32
Comprising			
Nitrate as N (mg/l)	5 (0)	5 (0)	32 (2)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	< (0)
Calcium (mg/l)	55	46	58
Sodium (mg/l)	71	66	60
Chloride (mg/l)	58	60	42
Sulphate (mg/l)	77	63	59
Trace Elements			
B (mg/l)	0.85	0.70	0.63
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10
Zn (mg/l)	0.12	0.12	0.12
Fe (mg/l)	<0.5	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Snow Queen, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	5.5	5.3	5.2	6.9	6.7	6.5	7.3	7.0	6.9
Conductivity (μS)	291 (1)	362 (2)	452 (3)	151 (1)	144 (0)	157 (1)	152 (1)	148 (0)	169 (1)
Density (g/l)	401	465	398	446	450	436	478	475	516
<u>Major Nutrients</u>									
Phosphorus (mg/l)	33 (5)	56 (7)	86 (8)	21 (4)	25 (4)	35 (5)	16 (3)	22 (4)	25 (4)
Potassium (mg/l)	23 (0)	46 (1)	95 (2)	153 (3)	107 (3)	113 (3)	161 (3)	124 (3)	143 (3)
Mg (mg/l)	113 (7)	141 (7)	176 (8)	5 (0)	8 (1)	11 (2)	4 (0)	7 (1)	8 (1)
Mineral nitrogen (mg/l)	103	141	193	12	8	23	6	8	22
Comprising									
Nitrate as N (mg/l)	103 (4)	141 (5)	191 (5)	11 (0)	8 (0)	22 (1)	6 (0)	7 (0)	22 (1)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	2 (0)	1 (0)	<1 (0)	1 (0)	<1 (0)	1 (0)	<1 (0)
Calcium (mg/l)	89	121	153	26	49	58	25	42	51
Sodium (mg/l)	82	91	93	70	72	72	72	73	74
Chloride (mg/l)	46	50	42	73	62	57	76	68	71
Sulphate (mg/l)	121	141	161	39	54	51	45	50	49
<u>Trace Elements</u>									
B (mg/l)	0.36	0.52	0.55	0.39	0.43	0.49	0.37	0.40	0.41
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.30	0.60	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	0.10	0.14	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	1.9	1.2	1.3	1.6	2.1	0.8

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Snow Queen, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	5.2	5.6	4.8
Conductivity (μS)	186 (1)	201 (1)	240 (1)
Density (g/l)	404	432	437
Major Nutrients			
Phosphorus (mg/l)	23 (4)	44 (6)	43 (6)
Potassium (mg/l)	110 (3)	130 (3)	124 (3)
Mg (mg/l)	19 (3)	20 (3)	26 (4)
Mineral nitrogen (mg/l)	52	71	111
Comprising			
Nitrate as N (mg/l)	52 (3)	69 (3)	111 (4)
Ammonia as N (mg/l)	<1 (0)	2 (0)	<1 (0)
Calcium (mg/l)	73	88	118
Sodium (mg/l)	65	66	56
Chloride (mg/l)	60	58	49
Sulphate (mg/l)	64	57	47
Trace Elements			
B (mg/l)	0.70	0.57	0.66
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	0.10	0.10	0.70
Zn (mg/l)	0.12	<0.10	0.29
Fe (mg/l)	0.6	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Star Gazer, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.2	5.9	5.9	7.2	7.0	7.1	7.6	7.6	7.7
Conductivity (μS)	149 (0)	253 (1)	300 (1)	187 (1)	184 (1)	172 (1)	116 (0)	121 (0)	154 (1)
Density (g/l)	292	299	426	469	481	489	527	497	552
<u>Major Nutrients</u>									
Phosphorus (mg/l)	8 (2)	42 (6)	54 (6)	20 (4)	25 (4)	29 (5)	14 (3)	21 (4)	16 (3)
Potassium (mg/l)	11 (0)	23 (0)	78 (2)	167 (3)	129 (3)	149 (3)	96 (2)	111 (3)	97 (2)
Mg (mg/l)	50 (5)	84 (6)	104 (7)	9 (1)	12 (2)	8 (1)	8 (1)	8 (1)	10 (1)
Mineral nitrogen (mg/l)	5	31	57	6	14	8	8	5	6
Comprising									
Nitrate as N (mg/l)	5 (0)	31 (2)	57 (3)	6 (0)	5 (0)	5 (0)	7 (0)	5 (0)	5 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)	<1 (0)	9 (0)	3 (0)	1 (0)	<1 (0)	1 (0)
Calcium (mg/l)	39	66	82	48	66	45	45	44	56
Sodium (mg/l)	61	125	93	83	80	78	58	69	69
Chloride (mg/l)	73	98	88	110	104	105	64	74	82
Sulphate (mg/l)	89	137	149	59	68	44	47	42	52
<u>Trace Elements</u>									
B (mg/l)	0.39	0.43	0.57	0.54	0.59	0.64	0.39	0.43	0.40
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	0.10	<0.10	<0.10	<0.10	0.10	<0.10	<0.10
Zn (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.41	0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	1.2	1.0	1.1	2.4	1.3	1.5

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Star Gazer, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	6.2	5.8	5.9
Conductivity (μS)	152 (1)	140 (0)	152 (1)
Density (g/l)	430	393	437
<u>Major Nutrients</u>			
Phosphorus (mg/l)	20 (4)	26 (4)	32 (5)
Potassium (mg/l)	127 (3)	79 (2)	87 (2)
Mg (mg/l)	9 (1)	12 (2)	14 (2)
Mineral nitrogen (mg/l)	5	5	5
Comprising			
Nitrate as N (mg/l)	5 (0)	5 (0)	5 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	31	42	49
Sodium (mg/l)	68	65	70
Chloride (mg/l)	84	79	70
Sulphate (mg/l)	64	60	74
<u>Trace Elements</u>			
B (mg/l)	0.54	0.63	0.73
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	<0.10	<0.10
Fe (mg/l)	0.7	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Star Gazer, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	5.7	5.5	5.4	6.9	6.9	6.9	7.7	7.6	7.3
Conductivity (μS)	250 (1)	371 (2)	428 (3)	238 (1)	215 (1)	184 (1)	160 (1)	136 (0)	155 (1)
Density (g/l)	301	325	401	461	457	475	520	542	542
Major Nutrients									
Phosphorus (mg/l)	23 (4)	59 (7)	89 (8)	26 (4)	27 (4)	29 (5)	19 (4)	24 (4)	23 (4)
Potassium (mg/l)	61 (2)	102 (3)	142 (3)	262 (5)	217 (4)	206 (4)	204 (4)	162 (3)	188 (4)
Mg (mg/l)	88 (7)	138 (7)	156 (8)	9 (1)	8 (1)	6 (1)	5 (0)	5 (0)	5 (0)
Mineral nitrogen (mg/l)	78	114	150	52	29	25	9	9	22
Comprising									
Nitrate as N (mg/l)	78 (3)	114 (4)	150 (5)	52 (3)	28 (2)	24 (1)	8 (0)	9 (0)	22 (1)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	72	112	132	49	45	38	29	32	27
Sodium (mg/l)	66	93	88	86	95	73	66	54	62
Chloride (mg/l)	67	95	86	108	116	99	82	58	75
Sulphate (mg/l)	101	159	162	45	52	29	27	16	24
Trace Elements									
B (mg/l)	0.37	0.47	0.53	0.53	0.45	0.46	0.37	0.35	0.35
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	0.30	<0.10	<0.10	<0.10	0.10	<0.10	<0.10
Zn (mg/l)	<0.10	0.13	0.10	<0.10	<0.10	<0.10	0.12	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	1.0	0.7	1.1	2.6	1.8	0.9

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Star Gazer, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	5.7	5.3	5.1
Conductivity (μS)	172 (1)	218 (1)	246 (1)
Density (g/l)	393	404	435
<u>Major Nutrients</u>			
Phosphorus (mg/l)	23 (4)	36 (5)	41 (6)
Potassium (mg/l)	191 (4)	204 (4)	205 (4)
Mg (mg/l)	8 (1)	17 (3)	21 (3)
Mineral nitrogen (mg/l)	38	78	101
Comprising			
Nitrate as N (mg/l)	38 (2)	78 (3)	101 (4)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	29	59	82
Sodium (mg/l)	66	70	64
Chloride (mg/l)	77	69	57
Sulphate (mg/l)	44	46	47
<u>Trace Elements</u>			
B (mg/l)	0.74	0.65	0.64
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	0.10
Zn (mg/l)	0.13	0.10	0.14
Fe (mg/l)	0.6	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Butter Pixie, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.4	6.6	6.7	6.9	6.8	6.8	7.2	7.1	7.1
Conductivity (μS)	155 (1)	145 (0)	126 (0)	182 (1)	207 (1)	204 (1)	196 (1)	237 (1)	250 (1)
Density (g/l)	370	455	362	398	384	431	437	428	450
Major Nutrients									
Phosphorus (mg/l)	<2 (0)	<2 (0)	<2 (0)	7 (1)	8 (2)	13 (3)	11 (2)	10 (2)	13 (3)
Potassium (mg/l)	8 (0)	10 (0)	10 (0)	29 (1)	23 (0)	23 (0)	46 (1)	63 (2)	49 (1)
Mg (mg/l)	23 (3)	20 (3)	15 (2)	14 (2)	14 (2)	14 (2)	15 (2)	19 (3)	22 (3)
Mineral nitrogen (mg/l)	9	7	7	7	11	8	7	7	7
Comprising									
Nitrate as N (mg/l)	9 (0)	7 (0)	7 (0)	7 (0)	9 (0)	8 (0)	7 (0)	7 (0)	7 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)	<1 (0)	2 (0)	<1 (0)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	46	45	44	106	124	122	100	136	168
Sodium (mg/l)	97	101	80	88	96	102	103	100	95
Chloride (mg/l)	101	102	79	98	110	108	118	129	116
Sulphate (mg/l)	80	76	65	105	111	114	96	133	153
Trace Elements									
B (mg/l)	0.43	0.45	0.37	0.29	0.29	0.37	0.35	0.036	0.35
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	7.6	<0.5	0.9

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Butter Pixie, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	6.3	6.1	6.2
Conductivity (μS)	137 (0)	138 (0)	142 (0)
Density (g/l)	369	358	362
Major Nutrients			
Phosphorus (mg/l)	2 (0)	4 (0)	2 (0)
Potassium (mg/l)	10 (0)	10 (0)	10 (0)
Mg (mg/l)	9 (1)	10 (1)	8 (1)
Mineral nitrogen (mg/l)	7	7	7
Comprising			
Nitrate as N (mg/l)	7 (0)	7 (0)	7 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)
Calcium (mg/l)	64	66	68
Sodium (mg/l)	80	80	82
Chloride (mg/l)	81	87	91
Sulphate (mg/l)	70	74	72
Trace Elements			
B (mg/l)	0.47	0.61	0.59
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Butter Pixie, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.1	6.3	6.1	6.7	6.9	6.9	7.2	7.1	7.2
Conductivity (μS)	219 (1)	199 (1)	223 (1)	209 (1)	184 (1)	207 (1)	244 (1)	246 (1)	193 (1)
Density (g/l)	401	347	401	405	472	417	491	460	514
<u>Major Nutrients</u>									
Phosphorus (mg/l)	3 (0)	4 (0)	4 (0)	13 (3)	9 (2)	12 (3)	12 (3)	15 (3)	13 (3)
Potassium (mg/l)	50 (1)	83 (2)	86 (2)	66 (2)	67 (2)	59 (2)	97 (2)	116 (3)	91 (2)
Mg (mg/l)	34 (4)	19 (3)	24 (3)	14 (2)	9 (1)	10 (1)	15 (2)	15 (2)	9 (1)
Mineral nitrogen (mg/l)	41	45	56	9	7	8	11	9	11
Comprising									
Nitrate as N (mg/l)	41 (2)	45 (2)	56 (3)	8 (0)	7 (0)	8 (0)	10 (0)	9 (0)	9 (0)
Ammonia as N (mg/l)	<1 (0)	<1 (0)	<1 (0)	1 (0)	<1 (0)	<1 (0)	1 (0)	<1 (0)	2 (0)
Calcium (mg/l)	78	67	82	108	80	93	109	108	70
Sodium (mg/l)	111	91	100	88	84	106	102	96	85
Chloride (mg/l)	87	85	98	92	90	111	119	127	108
Sulphate (mg/l)	114	82	90	119	96	108	129	122	83
<u>Trace Elements</u>									
B (mg/l)	0.35	0.25	0.33	0.32	0.24	0.23	0.30	0.32	0.27
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10	0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	<0.5	<0.5	0.9	<0.5	0.9	0.9	0.9	0.8

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Butter Pixie, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	6.1	6.1	6.1
Conductivity (μS)	168 (1)	165 (1)	159 (1)
Density (g/l)	400	396	380
<u>Major Nutrients</u>			
Phosphorus (mg/l)	4 (0)	4 (0)	3 (0)
Potassium (mg/l)	46 (1)	54 (2)	50 (1)
Mg (mg/l)	9 (1)	7 (1)	6 (1)
Mineral nitrogen (mg/l)	7	11	10
Comprising			
Nitrate as N (mg/l)	7 (1)	10 (0)	9 (0)
Ammonia as N (mg/l)	<1 (0)	1 (0)	1 (0)
Calcium (mg/l)	64	57	56
Sodium (mg/l)	87	87	84
Chloride (mg/l)	81	86	87
Sulphate (mg/l)	99	90	87
<u>Trace Elements</u>			
B (mg/l)	0.40	0.53	0.41
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10
Zn (mg/l)	<0.10	<0.10	<0.10
Fe (mg/l)	<0.5	0.5	0.6

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Memories, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	7.2	7.3	6.9	7.5	7.5	7.5	7.7	7.7	7.7
Conductivity (μS)	161 (1)	152 (1)	175 (1)	190 (1)	148 (0)	189 (1)	219 (1)	207 (1)	221 (1)
Density (g/l)	474	369	376	406	359	456	459	427	443
<u>Major Nutrients</u>									
Phosphorus (mg/l)	<2 (0)	<2 (0)	<2 (0)	9 (2)	7 (1)	12 (3)	10 (2)	14 (3)	13 (3)
Potassium (mg/l)	16 (0)	11 (0)	11 (0)	20 (0)	16 (0)	18 (0)	30 (1)	36 (1)	26 (1)
Mg (mg/l)	31 (4)	23 (3)	31 (4)	17 (3)	12 (2)	15 (2)	19 (3)	19 (3)	21 (3)
Mineral nitrogen (mg/l)	13	10	9	10	9	9	10	8	10
Comprising									
Nitrate as N (mg/l)	6 (0)	3 (0)	3 (0)	3 (0)	3 (0)	3 (0)	4 (0)	2 (0)	3 (0)
Ammonia as N (mg/l)	7 (0)	7 (0)	6 (0)	7 (0)	6 (0)	6 (0)	6 (0)	6 (0)	7 (0)
Calcium (mg/l)	51	48	66	118	89	114	138	133	152
Sodium (mg/l)	87	90	86	88	65	91	102	93	101
Chloride (mg/l)	81	87	87	84	57	91	94	83	94
Sulphate (mg/l)	89	81	107	105	81	97	111	104	116
<u>Trace Elements</u>									
B (mg/l)	0.35	0.29	0.45	0.36	0.28	0.32	0.32	0.35	0.34
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.10	<0.10	<0.10
Zn (mg/l)	0.13	0.13	0.15	0.16	0.12	0.16	0.16	0.16	0.13
Fe (mg/l)	<0.5	<0.5	<0.5	0.8	0.7	0.6	1.2	0.8	1.3

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Memories, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	6.9	6.7	7.1
Conductivity (μS)	138 (0)	138 (0)	172 (1)
Density (g/l)	457	318	367
Major Nutrients			
Phosphorus (mg/l)	2 (0)	3 (0)	3 (0)
Potassium (mg/l)	11 (0)	10 (0)	18 (0)
Mg (mg/l)	10 (1)	9 (1)	10 (1)
Mineral nitrogen (mg/l)	9	10	10
Comprising			
Nitrate as N (mg/l)	3 (0)	4 (0)	4 (0)
Ammonia as N (mg/l)	6 (0)	6 (0)	6 (0)
Calcium (mg/l)	63	63	89
Sodium (mg/l)	79	88	102
Chloride (mg/l)	118	81	106
Sulphate (mg/l)	69	74	76
Trace Elements			
B (mg/l)	0.41	0.46	0.39
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	<0.10	<0.10
Zn (mg/l)	0.13	0.17	0.12
Fe (mg/l)	0.5	<0.5	1.7

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Memories, +liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	6.5	6.4	6.3	7.3	7.2	7.1	7.6	7.1	7.4
Conductivity (μS)	261 (1)	273 (1)	256 (1)	223 (1)	230 (1)	215 (1)	249 (1)	269 (1)	235 (1)
Density (g/l)	275	573	327	411	349	415	424	461	407
Major Nutrients									
Phosphorus (mg/l)	8 (2)	20 (4)	10 (2)	14 (3)	16 (3)	20 (4)	19 (4)	26 (4)	23 (4)
Potassium (mg/l)	71 (2)	138 (3)	80 (2)	83 (2)	93 (2)	71 (2)	118 (3)	108 (3)	98 (2)
Mg (mg/l)	42 (5)	24 (3)	29 (4)	13 (2)	12 (2)	13 (2)	18 (3)	21 (3)	16 (3)
Mineral nitrogen (mg/l)	69	104	79	18	19	34	17	72	61
Comprising									
Nitrate as N (mg/l)	62 (3)	98 (4)	73 (3)	4 (0)	7 (0)	24 (1)	3 (0)	65 (3)	17 (1)
Ammonia as N (mg/l)	7 (0)	6 (0)	6 (0)	14 (0)	12 (0)	10 (0)	14 (0)	7 (0)	44 (1)
Calcium (mg/l)	99	99	100	93	98	105	122	157	106
Sodium (mg/l)	115	112	117	109	110	104	103	103	124
Chloride (mg/l)	92	100	94	86	87	78	82	76	101
Sulphate (mg/l)	124	79	103	119	126	98	140	109	110
Trace Elements									
B (mg/l)	0.30	0.31	0.27	0.28	0.29	0.32	0.35	0.43	0.37
Cu (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Mn (mg/l)	<0.10	0.10	<0.10	0.10	<0.10	0.10	<0.10	0.10	0.10
Zn (mg/l)	0.19	0.17	0.25	0.15	0.18	0.17	<0.10	0.19	0.21
Fe (mg/l)	<0.5	<0.5	<0.5	0.6	1.0	0.8	0.8	1.3	1.7

(continued)

Table B7 2001 Analysis of substrates at cropping, water extraction (a) cv Memories, +liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	6.7	6.4	6.5
Conductivity (μS)	218 (1)	213 (1)	252 (1)
Density (g/l)	374	321	363
Major Nutrients			
Phosphorus (mg/l)	15 (3)	10 (2)	11 (2)
Potassium (mg/l)	98 (2)	72 (2)	100 (2)
Mg (mg/l)	8 (1)	11 (2)	10 (1)
Mineral nitrogen (mg/l)	41	28	57
Comprising			
Nitrate as N (mg/l)	25 (1)	15 (0)	30 (2)
Ammonia as N (mg/l)	16 (0)	13 (0)	27 (1)
Calcium (mg/l)	62	80	80
Sodium (mg/l)	120	116	126
Chloride (mg/l)	100	92	94
Sulphate (mg/l)	102	123	134
Trace Elements			
B (mg/l)	0.24	0.36	0.34
Cu (mg/l)	<0.10	<0.10	<0.10
Mn (mg/l)	0.10	<0.10	<0.10
Zn (mg/l)	0.17	0.19	0.20
Fe (mg/l)	0.6	0.6	<0.5

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Brunello, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.2	4.0	4.0	4.4	4.5	4.5	4.7	4.8	4.9
Conductivity (µS)	2340	2350	2440	2210	2300	2300	2270	2270	2280
Major Nutrients									
Phosphorus (mg/l)	8	21	77	33	40	60	32	45	46
Potassium (mg/l)	30.2	22	49.8	95.1	93.3	102	151	147	114
Magnesium (mg/l)	494	464	494	119	110	116	109	113	117
Nitrate as N (mg/l)	<5	9	46	<5	<5	<5	<5	<5	<5
Ammonia as N (mg/l)	6	7	21	4	4	5	4	4	4
Sodium (mg/l)	80	76	70	67	65	70	62	64	69
Sulphur (mg/l)	101	104	153	69.6	67.7	67.3	45.4	48.7	64.7
Trace Elements									
Boron (mg/l)	0.60	0.74	0.76	0.77	0.71	0.75	0.76	0.77	0.78
Copper (mg/l)	0.65	0.70	0.69	0.69	0.77	0.69	0.89	0.97	0.98
Manganese (mg/l)	5.31	5.68	6.03	22.7	29.7	34.9	15.2	15.9	17.6
Zinc (mg/l)	3.11	3.71	3.89	12.5	12.7	13.0	13.1	14.2	14.5
Iron (mg/l)	23.2	23.2	23.7	59.4	61.9	65.1	59.8	66.6	64.6
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	6.4	0	0	0	0	1.6	3.1	3.5	1.8
10 mm–5 mm (% m/m)	13.8	8.5	5.6	6.0	8.6	6.0	13.0	7.3	15.9
5 mm-1 mm (% m/m)	59.0	41.1	36.1	53.8	53.5	48.9	54.3	62.3	55.6
<1 mm (% m/m)	20.8	50.4	58.3	40.2	37.9	43.5	29.6	26.9	26.7

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Brunello, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.7	3.6	3.6
Conductivity (µS)	2270	2260	2260
Major Nutrients			
Phosphorus (mg/l)	14	20	29
Potassium (mg/l)	59.6	47.5	60.9
Magnesium (mg/l)	105	94	104
Nitrate as N (mg/l)	<5	<5	<5
Ammonia as N (mg/l)	5	3	4
Sodium (mg/l)	62	55	51
Sulphur (mg/l)	71.1	56.5	60.2
Trace Elements			
Boron (mg/l)	1.58	1.14	1.02
Copper (mg/l)	1.27	0.98	0.81
Manganese (mg/l)	52.0	49.5	46.8
Zinc (mg/l)	12.0	10.3	9.95
Iron (mg/l)	47.5	43.3	44.3
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	3.7	3.7	0
10 mm–5 mm (% m/m)	5.4	4.8	2.3
5 mm-1 mm (% m/m)	53.7	52.0	56.1
<1 mm (% m/m)	37.2	39.5	41.6

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Brunello, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.0	3.9	3.9	4.4	4.1	4.3	4.5	4.6	4.7
Conductivity (µS)	2380	2430	2440	2280	2280	2270	2240	2260	2270
Major Nutrients									
Phosphorus (mg/l)	17	37	57	29	34	42	29	42	45
Potassium (mg/l)	50.1	63.2	99.1	159	123	129	179	199	166
Magnesium (mg/l)	446	475	403	107	85	94	94	100	100
Nitrate as N (mg/l)	63	79	110	<5	<5	<5	<5	<5	<5
Ammonia as N (mg/l)	7	6	6	4	4	6	5	6	6
Sodium (mg/l)	60	77	60	63	57	57	56	62	62
Sulphur (mg/l)	83.4	102	102	53.8	50.7	44.8	35.0	39.8	43.3
Trace Elements									
Boron (mg/l)	0.43	0.68	0.64	0.66	0.62	0.60	0.64	0.71	0.72
Copper (mg/l)	<0.50	0.86	0.63	0.62	0.61	0.57	0.73	0.83	0.97
Manganese (mg/l)	4.84	4.74	4.26	19.9	19.7	19.1	13.5	14.5	14.7
Zinc (mg/l)	2.77	3.48	3.29	11.2	10.5	10.6	12.1	13.3	13.4
Iron (mg/l)	17.8	49.9	43.4	44.5	50.0	56.2	52.6	33.8	33.6
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	0.5	0	0.9	0.9	4.1	0	5.8	0	0.5
10 mm–5 mm (% m/m)	5.2	6.9	5.6	3.1	3.2	7.2	8.2	8.7	5.4
5 mm-1 mm (% m/m)	35.2	43.2	49.6	54.6	50.3	48.0	54.7	54.1	53.6
<1 mm (% m/m)	59.2	49.9	43.9	41.4	42.4	44.8	31.3	37.2	40.5

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Brunello, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.6	3.8	3.7
Conductivity (µS)	2350	2280	2350
Major Nutrients			
Phosphorus (mg/l)	20	19	37
Potassium (mg/l)	109	97.1	126
Magnesium (mg/l)	85	82	103
Nitrate as N (mg/l)	52	16	60
Ammonia as N (mg/l)	5	5	6
Sodium (mg/l)	59	46	56
Sulphur (mg/l)	66.5	45.5	67.7
Trace Elements			
Boron (mg/l)	1.03	0.80	0.96
Copper (mg/l)	0.99	0.63	0.70
Manganese (mg/l)	25.0	37.5	37.7
Zinc (mg/l)	8.91	8.79	9.05
Iron (mg/l)	33.8	33.6	36.7
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	1.1	4.2	0
10 mm–5 mm (% m/m)	4.8	5.2	0.9
5 mm-1 mm (% m/m)	52.4	54.1	58.0
<1 mm (% m/m)	41.7	36.5	41.1

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Royal Fantasy, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.1	4.0	4.0	4.5	4.2	4.3	4.7	4.8	5.5
Conductivity (μS)	2250	2330	2390	2290	2260	2240	2250	2230	2230
Major Nutrients									
Phosphorus (mg/l)	17	39	109	38	33	45	30	44	54
Potassium (mg/l)	10.6	37.9	94.7	228	178	189	299	273	281
Magnesium (mg/l)	460	475	520	123	92	104	108	112	121
Nitrate as N (mg/l)	<5	19	55	<5	<5	<5	<5	<5	<5
Ammonia as N (mg/l)	7	6	16	5	5	7	8	9	7
Sodium (mg/l)	63	69	64	64	52	61	65	68	66
Sulphur (mg/l)	96.8	134	153	45.0	30.3	39.2	30.2	36.3	28.8
Trace Elements									
Boron (mg/l)	0.56	0.61	0.75	0.80	0.66	0.68	0.74	0.78	0.76
Copper (mg/l)	<0.50	0.57	0.67	0.84	1.12	0.58	0.89	0.98	1.20
Manganese (mg/l)	5.45	5.28	6.01	24.2	22.7	25.7	14.0	16.7	23.0
Zinc (mg/l)	3.12	3.28	3.95	13.5	10.8	11.4	13.0	14.5	17.0
Iron (mg/l)	20.5	21.4	23.3	63.8	49.2	47.6	53.7	60.9	70.9
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	2.4	3.8	0	1.8	3.1	0.7	6.8	7.4	4.7
10 mm–5 mm (% m/m)	9.5	6.4	5.9	8.4	5.7	5.4	6.8	10.3	14.3
5 mm-1 mm (% m/m)	36.5	38.5	42.3	49.4	50.5	49.4	52.7	53.9	52.6
<1 mm (% m/m)	51.6	51.3	51.8	40.4	40.7	44.5	33.7	28.4	28.5

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Royal Fantasy, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.7	3.8	3.7
Conductivity (µS)	2290	2270	2280
Major Nutrients			
Phosphorus (mg/l)	23	33	43
Potassium (mg/l)	113	113	153
Magnesium (mg/l)	114	113	109
Nitrate as N (mg/l)	<5	<5	<5
Ammonia as N (mg/l)	6	16	9
Sodium (mg/l)	71	71	58
Sulphur (mg/l)	69.5	57.7	53.1
Trace Elements			
Boron (mg/l)	1.90	1.78	1.40
Copper (mg/l)	1.66	1.52	1.24
Manganese (mg/l)	56.0	57.6	49.6
Zinc (mg/l)	14.1	14.6	11.5
Iron (mg/l)	53.5	52.5	47.3
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	1.1	0.8	0.5
10 mm–5 mm (% m/m)	5.8	1.9	4.1
5 mm-1 mm (% m/m)	47.8	50.3	54.5
<1 mm (% m/m)	45.3	47.0	40.9

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Royal Fantasy, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.2	4.1	4.1	4.9	4.8	4.8	5.6	5.5	5.5
Conductivity (µS)	2310	2340	2420	2250	2240	2270	2250	2230	2230
Major Nutrients									
Phosphorus (mg/l)	23	36	72	40	41	59	40	54	59
Potassium (mg/l)	42.6	76.6	133	299	240	234	361	322	324
Magnesium (mg/l)	452	456	453	117	102	107	119	114	114
Nitrate as N (mg/l)	36	57	86	<5	<5	7	<5	9	<5
Ammonia as N (mg/l)	8	8	12	5	5	4	4	5	5
Sodium (mg/l)	64	66	61	61	58	65	65	60	64
Sulphur (mg/l)	95.8	100	119	29.4	30.4	36.4	21.2	26.2	20.9
Trace Elements									
Boron (mg/l)	0.46	0.64	0.69	0.72	0.72	0.68	0.74	0.72	0.77
Copper (mg/l)	<0.50	0.63	0.66	0.73	0.86	0.72	0.98	0.98	0.98
Manganese (mg/l)	4.76	4.88	5.60	23.6	34.4	33.7	16.2	20.9	21.8
Zinc (mg/l)	2.71	3.37	3.68	12.9	12.3	13.2	16.1	16.0	15.6
Iron (mg/l)	19.3	20.5	22.8	71.7	61.0	65.5	66.3	69.7	69.2
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	1.9	1.7	0	1.6	0.9	1.4	0.1	7.9	2.1
10 mm–5 mm (% m/m)	6.5	7.3	3.1	4.6	3.6	7.2	9.7	15.3	15.5
5 mm-1 mm (% m/m)	44.1	33.9	40.8	55.0	51.2	52.5	56.9	56.8	62.8
<1 mm (% m/m)	47.5	57.1	56.1	38.8	44.3	38.9	33.3	19.7	20.2

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Royal Fantasy, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.8	3.8	3.8
Conductivity (µS)	2240	2250	2320
Major Nutrients			
Phosphorus (mg/l)	21	35	42
Potassium (mg/l)	176	164	191
Magnesium (mg/l)	97	97	98
Nitrate as N (mg/l)	6	20	50
Ammonia as N (mg/l)	8	7	5
Sodium (mg/l)	52	52	46
Sulphur (mg/l)	39.0	40.1	43.8
Trace Elements			
Boron (mg/l)	1.00	0.82	0.90
Copper (mg/l)	0.93	0.57	0.64
Manganese (mg/l)	51.9	48.3	49.2
Zinc (mg/l)	10.7	9.25	9.87
Iron (mg/l)	45.6	39.0	41.9
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	0.8	3.8	0.5
10 mm–5 mm (% m/m)	4.3	9.0	4.3
5 mm-1 mm (% m/m)	49.6	57.5	53.8
<1 mm (% m/m)	45.3	29.7	41.4

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Star Gazer, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.2	4.0	4.1	4.7	4.7	4.7	5.5	5.3	5.6
Conductivity (µS)	2300	2360	2350	2280	2290	2260	2230	2240	2240
Major Nutrients									
Phosphorus (mg/l)	8	43	53	42	56	62	46	63	53
Potassium (mg/l)	17.7	26.0	84.3	195	167	207	154	153	145
Magnesium (mg/l)	471	486	484	119	119	113	130	116	124
Nitrate as N (mg/l)	<5	27	50	<5	<5	<5	<5	<5	<5
Ammonia as N (mg/l)	6	6	6	5	6	8	6	4	6
Sodium (mg/l)	47	56	74	57	62	57	56	52	55
Sulphur (mg/l)	82.3	131	140	49.3	64.3	39.6	47.8	38.8	51.2
Trace Elements									
Boron (mg/l)	0.69	0.59	0.71	0.77	0.77	0.78	0.77	0.75	0.76
Copper (mg/l)	0.66	0.57	0.62	0.66	0.81	0.83	1.02	0.92	1.04
Manganese (mg/l)	6.45	4.80	4.33	29.4	33.0	32.2	17.8	18.7	21.9
Zinc (mg/l)	3.68	3.21	3.50	12.4	13.6	13.7	16.1	15.3	18.6
Iron (mg/l)	23.5	20.6	20.5	68.4	73.0	69.3	70.6	71.0	79.9
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	1.4	2.4	4.0	1.0	2.0	0.4	3.0	9.6	2.8
10 mm–5 mm (% m/m)	5.3	5.5	14.1	6.7	5.8	4.0	9.6	14.2	13.1
5 mm-1 mm (% m/m)	31.4	32.1	56.3	51.4	51.5	54.5	52.0	47.4	55.1
<1 mm (% m/m)	61.9	60.0	25.6	40.9	40.7	41.1	35.4	28.8	29.0

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Star Gazer, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.9	3.8	3.8
Conductivity (µS)	2170	2260	2250
Major Nutrients			
Phosphorus (mg/l)	25	31	35
Potassium (mg/l)	165	106	108
Magnesium (mg/l)	112	109	110
Nitrate as N (mg/l)	<5	<5	<5
Ammonia as N (mg/l)	7	5	4
Sodium (mg/l)	52	50	53
Sulphur (mg/l)	55.4	55.8	67.0
Trace Elements			
Boron (mg/l)	0.72	0.89	0.91
Copper (mg/l)	0.52	0.63	0.63
Manganese (mg/l)	43.0	49.0	47.4
Zinc (mg/l)	10.4	9.84	9.67
Iron (mg/l)	46.7	45.7	43.9
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	1.0	0.3	0.6
10 mm–5 mm (% m/m)	2.0	2.9	2.6
5 mm-1 mm (% m/m)	56.1	52.4	58.7
<1 mm (% m/m)	40.9	44.4	38.1

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Star Gazer, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.1	4.0	4.0	4.8	4.8	4.8	5.4	5.5	4.8
Conductivity (μS)	2380	2450	2490	2320	2310	2280	2220	2200	2260
Major Nutrients									
Phosphorus (mg/l)	23	53	80	51	56	58	44	93	53
Potassium (mg/l)	62.9	93.1	131	316	296	281	313	258	328
Magnesium (mg/l)	451	455	459	123	116	111	118	115	112
Nitrate as N (mg/l)	68	92	124	36	23	18	<5	6	21
Ammonia as N (mg/l)	7	5	8	5	6	4	5	5	5
Sodium (mg/l)	45	63	62	59	61	54	57	43	61
Sulphur (mg/l)	93.2	137	142	39.2	46.2	26.3	24.2	15.2	25.6
Trace Elements									
Boron (mg/l)	0.55	0.58	0.66	0.85	0.73	0.76	0.71	0.67	0.71
Copper (mg/l)	0.51	0.51	0.55	1.11	0.76	0.79	0.98	0.97	0.84
Manganese (mg/l)	6.02	4.20	3.97	32.0	33.2	30.5	18.0	16.5	13.7
Zinc (mg/l)	3.42	3.06	3.41	14.3	14.2	14.0	15.7	16.0	14.9
Iron (mg/l)	20.7	18.2	19.4	70.0	68.3	67.3	68.0	68.4	53.0
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	0.8	0.3	1.0	2.0	0.8	1.6	1.2	1.1	2.1
10 mm–5 mm (% m/m)	6.2	5.1	15.6	3.6	3.5	7.4	12.3	12.4	10.9
5 mm-1 mm (% m/m)	32.8	41.0	58.9	47.4	47.9	49.9	51.4	63.2	53.6
<1 mm (% m/m)	60.2	53.6	24.5	47.0	47.8	41.1	35.1	23.3	33.4

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Star Gazer, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.7	3.6	3.6
Conductivity (μS)	2320	2340	2360

Major Nutrients			
Phosphorus (mg/l)	27	38	44
Potassium (mg/l)	246	214	201
Magnesium (mg/l)	107	96	91
Nitrate as N (mg/l)	33	65	84
Ammonia as N (mg/l)	5	5	5
Sodium (mg/l)	49	44	37
Sulphur (mg/l)	37.7	41.1	40.3
Trace Elements			
Boron (mg/l)	0.89	0.78	0.77
Copper (mg/l)	0.71	0.67	0.62
Manganese (mg/l)	34.8	43.0	42.0
Zinc (mg/l)	11.2	9.15	8.96
Iron (mg/l)	39.8	42.2	39.0
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	0.7	0.6	0.2
10 mm–5 mm (% m/m)	0.8	3.2	0.7
5 mm-1 mm (% m/m)	48.2	51.8	55.3
<1 mm (% m/m)	50.3	44.4	43.8

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Snow Queen, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.2	4.1	4.0	4.8	4.2	4.4	4.6	4.4	4.5

Conductivity (µS)	2240	2330	2330	2220	2220	2240	2270	2250	2280
Major Nutrients									
Phosphorus (mg/l)	17	42	54	38	32	46	39	48	48
Potassium (mg/l)	13.3	16.5	34.3	163	74.5	110	170	132	145
Magnesium (mg/l)	456	457	431	121	93	103	108	96	98
Nitrate as N (mg/l)	10	23	41	<5	<5	<5	<5	<5	<5
Ammonia as N (mg/l)	5	7	14	5	6	5	5	5	5
Sodium (mg/l)	73	72	63	55	49	53	66	59	63
Sulphur (mg/l)	113	143	119	39.6	42.1	41.9	56.8	43.1	45.5
Trace Elements									
Boron (mg/l)	0.55	0.64	0.65	0.74	0.70	0.71	0.72	0.69	0.68
Copper (mg/l)	<0.50	0.59	0.62	0.81	0.64	0.60	0.88	0.77	0.76
Manganese (mg/l)	5.03	5.05	6.19	20.9	22.6	25.5	13.9	13.4	14.6
Zinc (mg/l)	3.01	3.27	3.97	13.1	10.4	11.3	13.3	11.7	12.3
Iron (mg/l)	20.1	20.7	22.7	68.5	51.0	51.6	56.0	54.3	56.3
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	1.7	2.3	0.1	5.0	1.0	2.5	3.5	1.3	3.9
10 mm–5 mm (% m/m)	12.1	5.7	5.4	7.3	6.7	4.2	8.9	11.3	9.4
5 mm-1 mm (% m/m)	62.1	39.4	32.1	54.8	60.2	54.1	55.5	56.6	54.5
<1 mm (% m/m)	24.1	52.6	62.4	32.9	32.1	39.2	32.1	30.8	32.2

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Snow Queen, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Snow Queen, + liquid feed

	1. Peat (new)	2.Eco-base + Sylvafibre 1:3 v/v	3. Eco-base + Sylvafibre 1:1 v/v
pH	3.6	3.6	3.5
Conductivity (µS)	2290	2280	2280
Major Nutrients			
Phosphorus (mg/l)	25	29	36
Potassium (mg/l)	73.8	77.7	96.7
Magnesium (mg/l)	110	101	89
Nitrate as N (mg/l)	<5	<5	26
Ammonia as N (mg/l)	5	7	6
Sodium (mg/l)	55	52	46
Sulphur (mg/l)	68.4	58.8	55.2
Trace Elements			
Boron (mg/l)	1.14	0.92	0.81
Copper (mg/l)	0.81	0.64	0.54
Manganese (mg/l)	39.6	35.5	30.0
Zinc (mg/l)	9.90	9.02	8.04
Iron (mg/l)	40.8	34.6	31.2
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	0	0.1	0
10 mm–5 mm (% m/m)	3.9	1.4	1.8
5 mm-1 mm (% m/m)	52.7	54.4	59.5
<1 mm (% m/m)	43.4	44.1	38.7

	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.0	4.0	3.9	4.6	4.6	4.4	5.2	4.9	5.0
Conductivity (μS)	2370	2390	2480	2240	2230	2270	2280	2250	2280
Major Nutrients									
Phosphorus (mg/l)	35	50	80	42	49	60	46	59	61
Potassium (mg/l)	27.8	46.8	92.9	227	155	148	290	193	224
Magnesium (mg/l)	459	410	475	123	114	107	125	116	123
Nitrate as N (mg/l)	97	117	169	<5	6	18	<5	<5	15
Ammonia as N (mg/l)	6	6	7	5	9	5	5	5	6
Sodium (mg/l)	63	68	65	65	67	64	77	73	72
Sulphur (mg/l)	123	125	147	36.9	52.2	49.0	41.1	47.3	43.9
Trace Elements									
Boron (mg/l)	0.56	0.63	0.69	0.70	0.76	0.74	0.77	0.77	0.78
Copper (mg/l)	0.51	<0.50	0.65	0.68	0.73	0.64	1.03	0.98	0.94
Manganese (mg/l)	4.99	3.74	5.17	18.5	29.2	27.9	17.1	17.8	17.7
Zinc (mg/l)	2.98	3.04	3.57	12.3	13.7	11.7	16.3	15.5	16.2
Iron (mg/l)	19.3	14.9	19.7	58.4	58.5	51.1	65.0	63.0	62.6
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	0	2.2	0.1	0.1	0.2	3.5	1.5	1.0	0.8
10 mm–5 mm (% m/m)	7.0	17.1	10.3	4.2	3.6	4.6	8.7	12.8	9.3
5 mm-1 mm (% m/m)	65.2	64.2	61.3	48.3	47.9	45.2	48.0	46.1	49.6
<1 mm (% m/m)	27.8	16.5	28.3	47.4	48.3	46.7	41.8	40.1	40.3

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Snow Queen, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	3.7	4.0	3.4
Conductivity (μS)	2320	2340	2420

Major Nutrients			
Phosphorus (mg/l)	32	60	47
Potassium (mg/l)	132	158	136
Magnesium (mg/l)	98	108	81
Nitrate as N (mg/l)	42	57	96
Ammonia as N (mg/l)	5	8	6
Sodium (mg/l)	50	55	39
Sulphur (mg/l)	58.0	55.0	46.0
Trace Elements			
Boron (mg/l)	0.92	0.80	0.85
Copper (mg/l)	1.37	0.69	0.74
Manganese (mg/l)	39.8	35.8	28.9
Zinc (mg/l)	9.78	10.3	8.16
Iron (mg/l)	48.5	46.1	31.8
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	0.5	1.4	0
10 mm–5 mm (% m/m)	5.2	3.5	1.6
5 mm-1 mm (% m/m)	51.8	53.2	61.4
<1 mm (% m/m)	42.5	41.9	37

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Butter Pixie, no liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.4	4.4	4.3	4.5	4.6	4.5	4.8	1.8	1.9
Conductivity (µS)	2230	2210	2220	2320	2320	2300	2280	2330	2310
Major Nutrients									
Phosphorus (mg/l)	1	<1	<1	25	31	42	43	51	53
Potassium (mg/l)	12.7	12.0	12.0	35.9	21.5	30.0	50.7	76.7	59.3
Magnesium (mg/l)	250	224	178	88	86	80	102	113	102
Nitrate as N (mg/l)	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ammonia as N (mg/l)	6	6	5	5	5	5	4	5	4
Sodium (mg/l)	84	89	74	78	80	87	75	87	85
Sulphur (mg/l)	71.4	70.4	62.9	105	102	112	83.5	127	112
Trace Elements									
Boron (mg/l)	0.85	0.82	0.77	0.66	0.61	0.74	0.71	0.75	0.68
Copper (mg/l)	1.04	1.03	0.83	0.78	0.95	0.98	0.97	1.01	1.04
Manganese (mg/l)	6.03	4.31	3.64	17.3	23.7	20.5	15.5	17.5	16.0
Zinc (mg/l)	4.44	4.16	3.68	10.4	11.1	11.4	13.4	14.4	13.8
Iron (mg/l)	22.7	20.7	19.5	50.4	63.9	66.4	60.4	67.6	64.0
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	0.6	5.0	0	1.7	0	0.7	1.4	4.5	2.7
10 mm–5 mm (% m/m)	14.0	20.1	14.3	3.4	8.2	3.1	9.2	7.1	12.3
5 mm-1 mm (% m/m)	58.6	62.6	68.4	48.9	47.9	60.1	49.0	56.0	55.8
<1 mm (% m/m)	26.8	12.7	17.3	46.0	43.9	36.1	40.4	32.4	29.2

(continued)

Table B8 2001 Analysis of substrates at cropping, DTPA/Cacl2 extraction (a) cv Butter Pixie, no liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	4.2	3.8	3.8
Conductivity (µS)	2260	2270	2250
Major Nutrients			
Phosphorus (mg/l)	7	6	5
Potassium (mg/l)	14.6	12.8	12.6
Magnesium (mg/l)	75	71	52
Nitrate as N (mg/l)	<5	<5	<5
Ammonia as N (mg/l)	4	5	5
Sodium (mg/l)	69	70	68
Sulphur (mg/l)	65.8	69.2	67.2
Trace Elements			
Boron (mg/l)	0.82	1.07	1.06
Copper (mg/l)	0.90	1.06	1.06
Manganese (mg/l)	35.3	31.4	27.4
Zinc (mg/l)	10.9	9.30	8.77
Iron (mg/l)	49.3	41.4	39.0
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	5.8	0.2	0
10 mm–5 mm (% m/m)	2.7	2.2	3.6
5 mm-1 mm (% m/m)	47.6	51.3	59.0
<1 mm (% m/m)	43.9	46.3	37.4

Table B8 2001 Analysis of substrates at cropping, DTPA/CaCl2 extraction (a) cv Butter Pixie, + liquid feed

	1. Peat (new)			2.Eco-base + Sylvafibre 1:3 v/v			3. Eco-base + Sylvafibre 1:1 v/v		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
pH	4.1	4.0	4.1	4.7	4.5	4.6	5.1	5.0	5.0
Conductivity (µS)	2280	2300	2290	2300	2270	2310	2330	2330	2300
Major Nutrients									
Phosphorus (mg/l)	5	6	6	35	31	37	48	54	50
Potassium (mg/l)	58.2	97.9	97.3	94.4	90.8	84.6	143	165	136
Magnesium (mg/l)	240	155	168	105	77	77	113	108	97
Nitrate as N (mg/l)	33	37	45	<5	<5	<5	<5	<5	<5
Ammonia as N (mg/l)	5	6	7	4	5	4	6	5	7
Sodium (mg/l)	102	77	89	84	79	105	101	91	84
Sulphur (mg/l)	108	78.4	84.2	107	85.7	104	112	113	78.4
Trace Elements									
Boron (mg/l)	0.60	0.55	0.60	0.64	0.54	0.52	0.68	0.66	0.62
Copper (mg/l)	0.76	0.74	0.81	0.94	0.76	0.76	1.21	0.95	0.93
Manganese (mg/l)	5.03	3.26	3.56	28.6	18.5	20.8	21.5	18.9	17.1
Zinc (mg/l)	3.72	3.69	3.83	13.9	11.0	12.0	16.3	15.2	14.7
Iron (mg/l)	21.5	19.9	21.4	66.9	53.7	58.4	66.2	63.6	59.6
Particle size									
>20 mm (% m/m)	0	0	0	0	0	0	0	0	0
20 mm-10 mm (% m/m)	0.7	0.7	2.9	1.9	0	0	4.0	3.6	6.8
10 mm–5 mm (% m/m)	13.6	15.7	10.6	4.4	6.0	3.8	7.1	12.5	7.5
5 mm-1 mm (% m/m)	65.1	59.7	65.2	46.7	55.2	50.0	46.6	51.2	55.0
<1 mm (% m/m)	20.6	23.9	21.3	47.0	38.8	46.2	42.3	32.7	30.7

(continued)

Table B8. 2001 Analysis of substrates at cropping, DTPA/$CaCl_2$ extraction (a) cv Butter Pixie, + liquid feed

	4. Sylvafibre + Grobark 7:3 v/v		
	Low	Medium	High
pH	4.1	4.1	4.1
Conductivity (µS)	2270	2280	2280
Major Nutrients			
Phosphorus (mg/l)	9	7	7
Potassium (mg/l)	68.7	77.1	75.8
Magnesium (mg/l)	75	67	54
Nitrate as N (mg/l)	<5	6	<5
Ammonia as N (mg/l)	5	6	5
Sodium (mg/l)	84	86	85
Sulphur (mg/l)	91.8	80.1	78.4
Trace Elements			
Boron (mg/l)	0.70	0.85	0.75
Copper (mg/l)	0.86	0.98	0.95
Manganese (mg/l)	33.8	36.6	31.0
Zinc (mg/l)	11.1	10.0	9.11
Iron (mg/l)	46.8	45.0	40.8
Particle size			
>20 mm (% m/m)	0	0	0
20 mm-10 mm (% m/m)	0.5	0	0.8
10 mm–5 mm (% m/m)	2.6	4.2	3.1
5 mm-1 mm (% m/m)	51.2	49.2	55.0
<1 mm (% m/m)	45.7	46.6	41.1

Table B9. 2001 experiment. Analysis of pale and normal green foliage at cropping.

	Brunello		*Royal Fantasy*		*Star Gazer*		*Snow Queen*	
	Pale	*Green*	*Pale*	*Green*	*Pale*	*Green*	*Pale*	*Green*
Dry matter (%)	8.7	8.7	11.9	10.1	15.2	13.7	11.7	9.3
N (%)	1.88	3.19	1.66	1.82	3.62	3.53	1.73	3.44
Ca (%)	1.16	1.31	1.16	1.42	1.18	1.52	0.89	1.04
K (%)	5.66	4.44	3.81	4.89	4.12	3.82	4.90	4.75
Mg (%)	0.27	0.60	0.28	0.39	0.17	0.57	0.17	0.49
P (%)	0.22	0.26	0.16	0.30	0.12	0.22	0.16	0.30
Mn (mg/kg)	42.2	60.9	61.6	102	31.5	103	35.0	64.7

Table B10. 2002 experiment. Analysis of substrate after addition of fertiliser. Water extraction.

	1. Peat			*2. Eco-base + Sylvafibre 1:3 v/v*			*3. Eco-base + Sylvafibre 1:1 v/v*			*4. Sylvafibre + Grobark 7:3 v/v*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	6	5.7	5.7	7	6.3	6.3	7.2	6.9	6.6	6.1	5.5	5.7
Conductivity (µS)	197 (1)	339 (2)	349 (2)	351 (2)	325 (2)	353 (2)	369 (2)	301 (2)	425 (3)	242 (1)	281 (1)	280 (1)
Density (g/l)	296	310	326	467	544	536	568	598	591	396	435	449
Major nutrients												
Phosphorus (mg/l)	56 (7)	117 (9)	100 (8)	50 (6)	85 (8)	86 (8)	73 (7)	67 (7)	45 (6)	81 (8)	73 (7)	62 (7)
Potassium (mg/l)	83 (2)	96 (2)	98 (2)	364 (5)	254 (5)	251 (5)	474 (6)	263 (5)	305 (5)	237 (4)	159 (3)	157 (3)
Mg (mg/l)	35 (4)	125 (7)	122 (7)	11 (2)	32 (4)	33 (4)	14 (2)	23 (3)	39 (5)	9 (1)	35 (4)	24 (3)
Mineral nitrogen (mg/l)	91	91	89	191	99	123	79	78	173	129	94	87
Comprising												
Nitrate as N (mg/l)	51 (3)	88 (4)	88 (4)	127 (4)	98 (4)	122 (4)	66 (3)	77 (3)	170 (5)	84 (4)	92 (4)	74 (3)
Ammonia as N (mg/l)	40 (1)	3 (0)	1 (0)	64 (2)	1 (0)	1 (0)	13 (0)	1 (0)	3 (0)	45 (1)	2 (0)	13 (0)
Calcium (mg/l)	28	117	116	50	153	176	68	121	200	29	123	89
Sodium (mg/l)	65	107	128	84	118	125	106	131	154	53	114	133
Chloride (mg/l)	41	94	111	143	127	126	226	125	141	73	98	109
Sulphate (mg/l)	66	143	153	8	70	69	32	63	73	20	74	76
Trace Elements												
B (mg/l)	0.11	0.59	0.66	0.5	1.08	1.15	0.64	0.88	0.98	0.3	1.46	1.4
Cu (mg/l)	< 0.10	< 0.1	< 0.10	< 0.10	< 0.1	< 0.10	0.22	0.11	< 0.10	< 0.10	< 0.10	0.2
Mn (mg/l)	0.1	0.2	0.4	0.1	0.1	0.3	0.1	0.1	< 0.10	0.2	0.3	1.8
Zn (mg/l)	0.28	0.39	0.39	0.38	0.43	0.41	0.39	0.31	0.39	0.4	0.61	0.71
Fe (mg/l)	< 0.5	< 0.5	< 0.5	1.8	1.1	0.9	2.4	1.8	1.4	1	0.6	0.7

Table B11. 2002 experiment. Analysis of substrate after addition of fertiliser. DTPA/$CaCl_2$ extraction.

	1. Peat			*2. Eco-base + Sylvafibre 1:3 v/v*			*3. Eco-base + Sylvafibre 1:1 v/v*			*4. Sylvafibre + Grobark 7:3 v/v*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	4	4.1	4.1	4.8	4.7	4.7	5.5	5.4	5.4	3.9	3.9	3.9
Conductivity (µS)	< 1500	< 1500	< 1500	< 1500	< 1500	< 1500	< 1500	< 1500	< 1500	< 1500	< 1500	< 1500
Major Nutrients												
Phosphorus (mg/l)	53	113	100	88	119	125	125	105	89	90	81	70
Potassium (mg/l)	100	102	106	495	300	283	612	323	322	344	183	184
Magnesium (mg/l)	387	461	468	134	174	157	149	167	173	128	158	131
Nitrate as N (mg/l)	44	81	78	110	86	109	60	63	158	73	78	73
Ammonia as N (mg/l)	48	5	5	83	5	158	16	4	7	57	2	24
Sodium (mg/l)	35	76	84	53	93	63.2	80	100	97	26	81	77
Sulphur (mg/l)	58.5	132	138	2.6	62.2	1.42	24.2	54.1	63.2	13.7	65.9	62.8
Trace Elements												
Boron (mg/l)	0.11	0.81	0.82	0.65	1.35	1.42	0.8	1.13	1.14	0.43	1.71	1.64
Copper (mg/l)	< 0.50	0.67	0.7	0.84	1.41	1.32	1.34	3.42	1.28	< 0.50	1.6	1.36
Manganese (mg/l)	3.16	7.15	9.37	37.7	48.9	47.2	17.5	21.5	34.9	55	72.7	69.7
Zinc (mg/l)	1.61	4.37	8.53	14.5	20.3	24.3	19.4	23.9	30.8	7.97	16.6	19.8
Iron (mg/l)	18.2	25.5	24.6	96.5	91.9	82.1	104	82.4	77	63.9	64.4	58.8

Table B12. 2002 experiment. Analysis of substrates after cropping, water extraction (a) cv Brunello

	1. Peat			*2. Eco-base + Sylvafibre 1:3 v/v*			*3. Eco-base + Sylvafibre 1:1 v/v*			*4. Sylvafibre + Grobark 7:3 v/v*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	6.6	6.5	6.1	6.7	6.8	6.7	7.3	7	7	6.5	6.1	6.4
Conductivity (µS)	134 (0)	132 (0)	210 (1)	148 (0)	126 (0)	132 (0)	147 (0)	195 (1)	198 (1)	91 (0)	154 (1)	107 (0)
Density (g/l)	394	463	452	454	516	534	545	563	563	406	437	442
Major nutrients												
Phosphorus (mg/l)	23 (4)	24 (4)	52 (6)	22 (4)	26 (4)	33 (5)	30 (5)	41 (6)	36 (5)	19 (4)	40 (5)	17 (3)
Potassium (mg/l)	15 (0)	4 (0)	3 (0)	88 (2)	26 (1)	31 (1)	135 (3)	58 (2)	55 (2)	39 (1)	11 (0)	11 (0)
Mg (mg/l)	37 (5)	34 (4)	68 (6)	11 (2)	11 (2)	12 (2)	9 (1)	19 (3)	17 (3)	6 (1)	21 (3)	8 (1)
Mineral nitrogen (mg/l)	8	3	13	4	8	6	4	23	19	3	4	3
Comprising												
Nitrate as N (mg/l)	8 (0)	3 (0)	13 (0)	3 (0)	7 (0)	5 (0)	3 (0)	22 (1)	18 (1)	3 (0)	4 (0)	3 (0)
Ammonia as N (mg/l)	< 1 (0)	< 1 (0)	< 1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	< 1 (0)	< 1 (0)	< 1 (0)
Calcium (mg/l)	34	39	69	55	59	64	48	100	96	29	76	39
Sodium (mg/l)	59	77	98	79	81	80	67	117	112	56	90	79
Chloride (mg/l)	46	66	89	103	72	71	80	94	97	59	70	62
Sulphate (mg/l)	73	74	123	52	46	46	43	71	76	34	82	51
Trace elements												
B (mg/l)	< 0.10	0.48	0.6	0.32	0.67	0.76	0.38	0.78	0.7	0.19	1.07	0.95
Cu (mg/l)	< 0.10	< 0.10	< 0.10	, 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Mn (mg/l)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.1	< 0.10	< 0.10	< 0.10
Zn (mg/l)	0.24	0.28	0.3	0.29	0.27	0.26	0.24	0.29	0.3	0.28	0.44	0.36
Fe (mg/l)	< 0.5	< 0.5	< 0.5	1.5	0.9	1	2.2	1.3	1.6	< 0.5	< 0.5	0.5

Table B12 (continued). 2002 experiment. Analysis of substrate after cropping, water extraction (b) cv Star Gazer.

	1. Peat			*2. Eco-base + Sylvafibre 1:3 v/v*			*3. Eco-base + Sylvafibre 1:1 v/v*			*4. Sylvafibre + Grobark 7:3 v/v*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	6.5	6.8	6.4	7.1	6.8	6.9	7.5	7.2	7.3	6.4	6.5	6.3
Conductivity (µS)	109 (0)	175 (1)	211 (1)	127 (0)	159 (1)	147 (0)	150 (0)	174 (1)	176 (1)	108 (0)	121 (0)	156 (1)
Density (g/l)	415	429	449	458	537	522	560	580	579	421	448	452
Major nutrients												
Phosphorus (mg/l)	13 (3)	38 (5)	39 (5)	18 (3)	33 (5)	30 (5)	32 (5)	37 (5)	24 (4)	33 (50	23 (4)	28 (4)
Potassium (mg/l)	26 (1)	19 (0)	32 (1)	126 (3)	63 (2)	62 (2)	152 (3)	99 (2)	87 (2)	91 (2)	33 (1)	37 (1)
Mg (mg/l)	24 (3)	44 (5)	56 (6)	5 (0)	13 (2)	11 (2)	8 (1)	12 (2)	12 (2)	6 (1)	11 (2)	14 (2)
Mineral nitrogen (mg/l)	6	3	14	4	9	8	4	24	9	3	6	9
Comprising												
Nitrate as N (mg/l)	6 (0)	3 (0)	14 (0)	3 (0)	8 (0)	7 (0)	3 (0)	23 (1)	8 (0)	3 (0)	6 (0)	8 (0)
Ammonia as N (mg/l)	< 1 (0)	< 1 (0)	< 1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	< 1(0)	< 1 (0)	1 (0)
Calcium (mg/l)	23	61	61	27	67	58	39	70	70	23	45	64
Sodium (mg/l)	55	88	101	65	93	85	69	93	100	53	71	85
Chloride (mg/l)	57	86	102	90	84	80	78	84	97	64	69	80
Sulphate (mg/l)	49	100	108	34	61	46	37	47	67	37	51	73
Trace elements												
B (mg/l)	0.1	0.46	0.57	0.29	0.83	0.75	0.39	0.66	0.69	0.22	0.89	0.98
Cu (mg/l)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Mn (mg/l)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.1	0.1	0.1	0.1	< 0.10	< 0.10	< 0.10
Zn (mg/l)	0.26	0.33	0.42	0.31	0.28	0.32	0.3	0.37	0.44	0.35	0.42	0.49
Fe (mg/l)	< 0.5	< 0.5	< 0.5	1.4	1.3	1.4	2.9	2.4	2.3	0.6	< 0.5	0.5

Table B13. 2002 experiment. Analysis of substrate after cropping, DTPA/CaCl2 extraction (a) cv Brunello

	1. Peat			*2. Eco-base + Sylvafibre 1:3 v/v*			*3. Eco-base + Sylvafibre 1:1 v/v*			*4. Sylvafibre + Grobark 7:3 v/v*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	4.3	4.5	4.3	4.9	5	4.9	5.5	5.5	5.6	4.2	4.2	4.2
Conductivity (µS)	2190	2160	2270	2220	2220	2190	2220	2300	2260	2190	2250	2160
Major Nutrients												
Phosphorus (mg/l)	25	30	54	48	55	66	81	84	82	27	46	25
Potassium (mg/l)	14	6	6	110	27	49	226	73	89	55	14	11
Magnesium (mg/l)	402	392	424	127	139	138	145	177	169	106	141	107
Nitrate as N (mg/l)	8	< 5	14	< 5	5	< 5	< 5	22	17	< 5	< 5	< 5
Ammonia as N (mg/l)	< 1	1	2	< 1	1	2	1	1	2	1	2	2
Sodium (mg/l)	53	66	84	66	76	76	60	124	113	44	81	68
Sulphur (mg/l)	74.1	71.2	113	43.3	43.7	42.9	42.5	84.2	77.8	32.4	73.7	49.6
Trace Elements												
Boron (mg/l)	0.18	0.78	0.87	0.59	1.16	1.31	0.73	1.18	1.21	0.32	1.45	1.48
Copper (mg/l)	< 0.50	0.71	0.74	0.56	1.26	1.88	1.04	1.28	1.33	< 0.50	1.51	1.41
Manganese (mg/l)	3.67	5.97	7.74	33.2	36.6	32.5	14.6	17.8	15.4	51.1	64.9	55.4
Zinc (mg/l)	1.52	4.16	8.91	14.2	20.9	24.2	20.2	27.9	26.3	8.52	17.3	19.7
Iron (mg/l)	17.5	23.9	22.6	88	81.9	73.9	96.5	84.7	80.6	60.7	63.4	55.8

Table B13 (continued). 2002 experiment. Analysis of substrate after cropping , DTPA/$CaCl_2$ extraction (b) cv Star Gazer.

	1. Peat			*2. Eco-base + Sylvafibre 1:3 v/v*			*3. Eco-base + Sylvafibre 1:1 v/v*			*4. Sylvafibre + Grobark 7:3 v/v*		
	New	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*	*New*	*Used*	*Used + sterilised*
pH	4.3	4.5	4.4	4.8	5.1	5	5.6	5.5	5.6	4.1	4.3	4.2
Conductivity (µS)	2140	2210	2230	2210	2250	2200	2230	2240	2240	2210	2220	2270
Major Nutrients												
Phosphorus (mg/l)	16	39	46	48	63	58	81	78	60	45	35	48
Potassium (mg/l)	19	18	25	216	99	89	261	136	121	139	47	51
Magnesium (mg/l)	375	389	402	119	147	129	148	145	151	121	136	121
Nitrate as N (mg/l)	< 5	< 5	13	< 5	5	< 5	< 5	19	< 5	< 5	< 5	6
Ammonia as N (mg/l)	< 1	1	2	< 1	3	2	2	2	2	1	1	1
Sodium (mg/l)	43	60	72	52	81	57	60	70	70	36	63	64
Sulphur (mg/l)	53	87.8	105	32.2	60.6	37.9	36.5	37.9	68.6	35.5	54.9	93.4
Trace Elements												
Boron (mg/l)	0.21	0.81	0.95	0.64	1.31	1.18	0.76	1.03	1.1	0.36	1.45	1.49
Copper (mg/l)	< 0.50	0.71	0.9	0.66	1.33	1.19	1.11	1.22	1.11	< 0.50	1.48	1.4
Manganese (mg/l)	3.52	6.13	8.22	34.9	37.9	33.9	14.2	19.1	19.3	53.9	63.8	56.1
Zinc (mg/l)	1.54	4.42	9.51	13.8	21.2	25.3	20.4	23.1	32.5	8.39	17.1	20.6
Iron (mg/l)	17.5	25.7	24.9	101	80.2	78.4	99.5	85.2	76.2	60.7	64.9	57.7

Table B14. 2002 experiment. Analysis of pale and normal foliage of cv Star Gazer.

	Pale foliage	*Dark foliage*
Dry matter (%)	65.9	45.9
N (%)	1.53	2.64
Ca (%)	2.12	2.5
K (%)	3.3	2.78
Mg (%)	0.16	0.41
P (%)	0.12	0.16
Mn (mg/kg)	25.9	58.6