REPORT FOR HDC
BULB FORCING: THE USE OF PEAT SUBSTITUTES OR EXTENDERS

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BULB FORCING: THE USE OF PEAT SUBSTITUTES OR EXTENDERS

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BULB FORCING: THE USE OF PEAT SUBSTITUTES OR EXTENDERS

SUMMARY

1. Early, middle-season and late forcing rounds each of narcissus Golden Harvest and tulips Paul Richter and Apeldoorn were grown in peat (baled or bulk loose), coir, bark, coir mix (coir/straw/manure mixture) and soil. In narcissus, the major effects due to substrate were on stem length: the first forcing round produced short crops when soil was used, and later rounds gave short crops when raised in coir mix. In tulips, the yield and length of marketable blooms were strongly affected by substrate. For Paul Richter, the first forcing round had low yields in coir, bark, and coir mix, and coir mix, bulk peat and soil gave shorter stems; in the second round, baled peat and coir gave low yields, and soil shorter stems; and in the third round, coir mix and soil gave low yields, and coir mix, bulk peat and soil shorter stems. In the first round of cv Apeldoorn, there was extensive bud blasting in all substrates except soil; in later rounds, bark or soil produced short-stemmed plants, but other substrates were generally satisfactory.

2. The forcing of narcissus Golden Harvest and tulip Apeldoorn in peat was compared with growing in shredded paper (glazed or unglazed), sawdust, wood shavings, rockwool (granular or shredded used blocks) and chopped straw (either a local or a proprietary material); these materials were also evaluated using a sand cover, or mixed in equal volumes with peat. Forcing narcissus in glazed paper or chopped straw (alone) delayed cropping, and yields were reduced, and (or) average stem lengths reduced (compared with peat), using glazed paper, chopped straw, shredded rockwool blocks and sawdust. Other materials, and mixtures with peat, gave acceptable results. In tulip, cropping was delayed using shredded paper, sawdust, wood shavings, rockwool and, especially, chopped straw. Only the following materials resulted in yields comparable with those in peat: unglazed paper plus peat, rockwool (alone or with peat) and chopped straw.

3. Narcissus Golden Harvest and tulip Lucky Strike were forced as pot-plants in peat, coir, bark, soil or sawdust. For narcissus, all substrates produced acceptable products; plants in bark and sawdust were shorter than others, but dwarfing with ethephon was successful in all substrates. For tulip, anchorage of bulbs in sawdust was poor and in this substrate the retardant paclobutrazol was ineffective; in other substrates the product was acceptable and the retardant was effective, stems being shorter in bark and soil.

4. Lily cultivars Connecticut King and Star Gazer were forced as tray-grown crops in peat (baled or bulk loose), soil, coir, bark, coir mix, shredded glazed paper, sawdust, granular rockwool or chopped straw. The nutrient levels of each were standardized before use by the addition of fertilisers. In both cultivars, rockwool, sawdust, paper, straw, and bark produced pale foliage. Paper, soil, rockwool, sawdust and straw resulted in delayed cropping and shorter stems. In Connecticut King, more florets aborted when soil was used. There were other adverse effects of these substrates on flower size and the length of basal stem bearing dead leaves.

INTRODUCTION

Background and objectives

The controversy about the use of peat products in horticulture is well known, and has been the subject of an HDC-funded review (Bragg, 1991). Although bulb forcing accounts for only a small proportion of the peat used in UK horticulture, the simple nutritional requirements of narcissus (daffodil) and tulip offer an excellent opportunity for switching from peat to other substrates. These bulbs contain the reserves necessary to produce a marketable bloom without additional feeding, with the possible exception of calcium (and sometimes boron) in the case of tulips. Essentially, the growing medium or substrate is there to provide physical support and hold air and water. Management factors such as ease of handling, uniformity and freedom from dust and pathogenic organisms, are important. On the other hand, for lily bulbs the glasshouse growing period is much longer, with a dependence on photosynthesis for flower production, and nutritional requirements are much more stringent. Lily bulbs are conventionally forced in the glasshouse soil, rather than in trays, but soil-borne diseases and the need to reduce pesticide inputs, and frequent problems with iron and manganese deficiency induced by soils of high pH, have prompted a move towards growing lilies in trays, like narcissus or tulip. As long as attention is paid to careful irrigation and the development of a good root system, tray forcing of lilies is a successful technique.

There are several potential advantages to bulb forcers of investigating alternatives to peat for use as substrates. From the environmental viewpoint, using a 'greener' material could improve image, and make an added selling point. This would be particularly pertinent as far as pot-grown bulbs were concerned, where the potting medium is obvious to the consumer. From the viewpoint of costs, it might be possible to reduce these by using a suitable, locally available waste material. In the UK, the number of bulbs forced is fairly stable, and currently over 100 million narcissus bulbs, and about 70 million tulips, 20 million lilies and 10 million irises are forced annually. Statistics for recent years are given in Table 1. Besides the UK, of course, very large bulb forcing industries exist in the Netherlands and elsewhere in Europe.

Using peat alternatives, including waste products, is a topical issue, and it is timely to investigate bulb forcing in different substrates. Inevitably, with a plethora of candidate materials available, it was difficult restricting the number of materials to be examined. It was agreed that the specific aims of this HDC-funded work, in its first year, would be to examine narcissus and tulip forcing:

(1) in peat, soil and a selection of proprietary ('off-the-shelf') non-peat substrates. Golden Harvest narcissus and two contrasting types of tulip (the Darwin Hybrid cv Apeldoorn and the Triumph tulip cv Paul Richter) were used, three successive rounds being forced in an attempt to find any interactions with plant stress when forced early or late in the season.

(2) in a wide range of potentially useful materials including wastes. Golden Harvest narcissus and Apeldoorn tulips were forced mid-season, either in the non-peat material alone or mixed in equal volumes with peat. Because there are many different sources or variants of waste material, two representative sorts were chosen for each main material, such as sawdust and wood shavings for wood waste, and glazed and unglazed paper.

(3) as pot-plants, in a more restricted range of consumer-acceptable materials. Suitable varieties (narcissus Golden Harvest and tulip Lucky Strike) were grown in pots, and the interaction between substrate type and the use of a retardant was investigated.

As a fourth part of the HDC project, lily bulbs were forced in a wide range of representative non-peat materials. Two important but contrasting cultivars were used, the Asiatic hybrid Connecticut King, and the Oriental lily Star Gazer. The trial was duplicated using two forcing routines, ie, with or without an initial cold storage period (designed to encourage good early rooting with a saving of time in the glasshouse). As our knowledge of the performance of lilies in non-peat or non-soil substrates was more rudimentary than that for narcissus and tulip, the trial was very much a preliminary one.

Current recommendations and previous trials on substrates

Narcissus and tulip Current recommendations for narcissus and tulip forcing are to use a tray about 8 to 11 cm deep. For narcissus, about 4 to 6 cm of thoroughly wetted medium grade sphagnum peat is used, planting the bulbs close together on top and covering with a further layer of peat or sand (ADAS, 1985). Provided the pH of the peat is not below 4.0, no liming is necessary, and satisfactory forcing has been achieved even in peat of pH 3.2 (Briggs, 1976a).

For tulip, the recommendations are similar, using a 6 to 8 cm layer of limed peat. To increase the pH of the peat, ground chalk or limestone is added, at a rate of 2 to 3 kg per m^3 for each pH unit rise required, to bring the pH to 6.5 (ADAS, 1981). Although a pH as low as 5.0 can be used, better results are obtained if the pH is 6.0 or above (Briggs, 1976b).

It is widely understood that no appreciable nutrient levels are needed, and that high salt levels may damage tulip roots (Rees, 1992; Buschman and Roozen, 1980). Increased bulb nitrogen content, brought about by earlier fertilizing, can increase bud blasting when tulip bulbs are exposed to ethylene during forcing (de Munk *et al.*, 1980), and the salt content of substrate also affects the incidence of veinal streak disorder (Asjes and Muller, 1973). Tulips can, however, exhibit two types of deficiency. If forced bulbs are grown under acid conditions, at too high a temperature or relative humidity, low calcium levels may develop, leading to a stem collapse known as topple or water-neck. Under suspect conditions, a calcium nitrate drench or spray treatment may be used (ADAS, 1981; De Hertogh, 1989). Secondly, boron deficiency can lead to deformities including stem breaking, and borax may be added to remedy this (IFBC, 1991). However, De Hertogh *et al.* (1978) and Volf and Zlebcik (1984)

Table 1. Numbers of bulbs (millions p. a.) forced in England and Wales

Winter Season	Narcissus	Tulip	Others	Calendar year	Lily	Iris
1991/92	107.0	68.2	7.3	-	-	-
1990/91	100.1	66.6	6.0	1991	19.5	10.0
1989/90	103.6	77.0	8.5	1990	20.6	9.9
1988/89	92.6	84.6	9.7	1989	23.2	11.0
1987/88	99.6	88.8	6.4	1988	20.4	13.4
1986/87	81.9	78.9	8.1	1987	22.6	13.0
1985/86	80.7	73.3	12.7	1986	21.9	13.6
1984/85	83.4	71.1	12.4	1985	16.7	12.2

* source: MAFF (December censuses)

demonstrated decreased bud abortion and larger and heavier flowers in tulips (forced using the '5°' system) following top dressing with calcium nitrate, NPK fertiliser or controlled release fertiliser, while Mugge *et al.* (1987) demonstrated faster and more productive forcing with tulip bulbs which had previously received higher nitrogen applications. Dutch literature recommends adding fertiliser to substrates used for tulips (eg, 0.4 kg 14:16:18 N:P:K with trace elements per m^3) (IFBC, 1991).

Soil was formerly used as a forcing substrate for narcissus and lilies, being replaced by peat because of the latter's lightness. Dutch recommendations are for mixtures of peat and soil or sand (IFBC, 1991), and De Hertogh (1989) mentions various planting media. There have been some earlier reports of using alternative material for forcing these bulbs, such as pulverized bark (Forestry Commission, 1972), mixtures of rice hulls with soil, sand and peat (Einert and Baker, 1973), and soil, sand, scoria and rice hull mixes (Roh *et al.*, 1979). Forcing of tulips in hydroponic systems with calcium nitrate (Klougart, 1980; Nelson, 1984) and of narcissus in aeroponic systems (Vincenzoni, 1981) have been demonstrated successfully.

Lily The following nutritional levels have been suggested for border soil lily flower production from glasshouse plantings (ADAS, 1984): pH 6.0-6.5, 40-60 mg N/litre, 50-70 mg P/litre, 350-500 mg K/litre, 40-80 mg Mg/litre; conductivities over 2700 μs inhibit rooting and induce chlorosis. A typical base fertiliser for forcing would be 3 to 4 kg/100 m^2 of a 12:10:18 N:P:K compound fertiliser (ADAS, 1984). In high pH soils (above 7.2) (such as found in some bulb forcing areas of Lincolnshire) iron and manganese deficiencies are a common problem in lily growing, and corrective sprays of chelates are required (ADAS, 1986).

Concerns about the intensive use of pesticides in the bulbs industry prompted the investigation of forcing lilies in trays of substrate (Anon., 1990) which avoids the need for soil sterilisation, and could reduce fungicide incorporation, both of which are necessary to control *Pythium* and *Rhizoctonia* when crops are grown repeatedly in the same glasshouse, as well as overcoming problems of high-pH soils. Container-grown lilies may be raised in, for example, GCRI peat-sand potting compost (Hanks and Menhenett, 1980; MAFF, 1988) or medium grade sphagnum peat limed to pH 6.5 and amended with controlled release fertiliser (ADAS, unpublished data). Dutch recommendations for forcing lilies in trays involve the use of peat-based substrates with the addition of fertilisers such as PG-mix (14:16:18 N:P:K) (van der Boon and Niers, 1986, 1987). Leaf tip scorch is a problem in some cultivars where fluorine occurs as a contaminant of fertilisers such as superphosphate (Roorda van Eijsinga, 1980) and can be avoided by substituting dicalcium phosphate (Menhenett and Hanks, unpublished data). Little is known of the performance of forced lilies in alternative substrates.

MATERIALS AND METHODS

Narcissus experiments

Plant material Bulbs of *Narcissus* cultivar Golden Harvest, graded 12/14 cm (circumference, slotted riddle) were taken from a stock grown at HRI Kirton. For the first round of experiment 1 only, bulbs were warm-stored after lifting (5 days at 35°C); otherwise storage until required was at 17°C.

Experiment 1 ('proprietary' materials) Batches of narcissus Golden Harvest bulbs were placed in a cold store (9°C) on 6 August, 17 September and 8 October 1991. They were planted in trays (see below) on 17 September, 29 October and 19 November, respectively, and returned to the 9°C cold store.

The three batches were moved to a glasshouse (minimum maintained temperature 16°C, ventilated at 18°C) on 19 November 1991, 2 January 1992 and 21 January 1992, respectively.

The following substrates were used in this experiment: baled peat, local bulk peat, coir, bark, coir mix and soil (see 'Substrates'(below) and Table 2 for further details). All materials were used without any amendments. Bulbs were planted in wooden 'dual-purpose trays' (61 x 45 x 11 cm): a 6 cm deep layer of substrate was placed in the tray, 97 bulbs were evenly placed across the tray by hand, and the bulbs were covered with further substrate to the top of the tray. Trays were watered well before being placed in the cold store, and during cold storage were inspected at least weekly to ensure the substrate remained sufficiently moist.

Root growth and crop support were compared with that in the standard baled peat substrate when the crops were moved to the glasshouse. Marketable blooms were cropped daily each morning at a 'fat pencil' stage. Stems were graded by length, and the daily pick in each grade recorded. At the end of the cropping period, the numbers of any unmarketable blooms and of bulbs which had produced non-viable flowers were noted, along with the reason for failure.

Ten representative blooms from these treatments were placed in a jar of plain water in a vase-life test room with fresh air circulation, at 18°C and 65 percent relative humidity under tubular fluorescent lighting (12 hours per day). The individual dates of flower senescence (taken as the withering of the tips of the outer three perianth segments) were recorded.

Experiment 2 ('waste' materials) Narcissus Golden Harvest bulbs were placed in a cold store (9°C) on 13 August 1991, planted in trays (see below) and returned to the store on 24 September, and moved to a glasshouse (16°C) on 26 November.

The following substrates were used: baled peat, shredded glazed paper, shredded unglazed paper, sawdust, wood shavings, granular rockwool, shredded used rockwool blocks, chopped straw and proprietary chopped straw (see 'Substrates' (below) and Table 2). The non-peat substrates were either used alone, alone but with a covering of sand, or mixed with an equal volume of baled peat. All materials were used without amendments. Planting in trays was as described above for experiment 1. The crop was also assessed as for the preceeding experiment.

Experiment 3 (pot-plant experiment) Narcissus Golden Harvest bulbs were placed in a cold store (9°C) on 17 September 1991, planted in pots (see below) and returned to the cold store on 23 October, and housed (16°C) on 30 December 1991.

The following substrates were used: baled peat, coir, bark, soil and sawdust (see 'Substrates' (below) and Table 2). Five bulbs were planted in each 14 cm diameter plastic half-pot, such that the bulb tip emerged at the top of the pot. Pots were watered well before cold-storage and kept sufficiently watered in storage. Half of the pots of each substrate were drenched with ethephon solution, the remaining pots receiving a plain water drench as a control. Ethephon (as 1 ml Ethrel C diluted to 1 litre, 80 ml/pot) was applied one day after housing (31 December), when mean shoot lengths for the different substrates were 10 to 13 cm.

Root growth and crop support were assessed. The dates when half the flowers in a pot had reached a marketable stage (fat pencil), and when half had begun to senesce, were recorded, along with the lengths of all stems at these dates, which were used to produce pot mean lengths and shelf-lives. The number of viable flowers produced in each pot was also recorded.

Tulip experiments

Plant material Bulbs of *Tulipa* cultivars Apeldoorn, Lucky Strike and Paul Richter were taken from stocks grown at HRI-Kirton: the bulb grade (round riddle) used was 11/12 cm, except for the first round of experiment 1 (12/13 cm) and the third round of experiment 1 (10/11 cm). For the first round of experiment 1 only, bulbs were warm-stored after lifting (5 days at 35°C). Otherwise, storage until required was at 20°C until the end of August and then 17°C.

Tulip crops were sprayed one and 14 days after housing with chlorothalonil plus non-ionic wetter (as 30 ml Repulse plus 6 ml Agral per 10 litres, HV spray) for control of tulip fire (*Botrytis tulipae*).

Experiment 1 ('proprietary' materials) Batches of tulip Apeldoorn bulbs were cold stored at 9°C on 6 August, 20 August and 17 September 1991, planted in trays (see below) and returned to the cold store on 17 September, 1 October and 29 October, and moved to a glasshouse (minimum maintained temperature 18°C, ventilated at 20°C) on 2 January, 14 January and 11 February 1992, respectively.

Batches of tulip Paul Richter were similarly treated: cold storage dates were 13 August, 10 September and 24 September 1991; planting dates were 17 September, 23 October and 5 November; and housing dates were 17 December 1991, 7 January and 28 January 1992.

The same six substrates were used as for the narcissus experiment 1. Peat substrates were adjusted to pH 7.0 using 2.4 kg lime per m^3 per pH unit rise required (see 'Substrates' (below) and Table 6). Bulbs were planted in wooden 'dual-purpose trays' (61 x 45 x 11 cm): an 8 cm deep layer of substrate was placed in the tray and 65 bulbs were evenly placed across the tray by hand and covered with further substrate to the top of the tray. Trays were watered well before being placed in the cold store, and during cold storage were inspected at least weekly to ensure the substrate remained sufficiently moist.

Root growth and crop support were compared with that in the standard baled peat substrate when the crops were moved to the glasshouse. Marketable blooms were cropped daily each morning, when the bud had begun to show colour. Stems were graded by length, and the daily pick in each grade recorded. At the end of the cropping period, the numbers of any unmarketable blooms and of bulbs which had produced non-viable flowers were noted, along with the reason for failure.

Ten representative blooms from these treatments were placed in a jar of plain water in a vase-life test room with fresh air circulation, at 18°C and 65 per cent relative humidity under tubular fluorescent lighting (12 hours per day). The individual dates of flower senescence (taken as the withering of the tips of the outer three perianth segments) were recorded.

Experiment 2 ('waste' materials) Tulip Apeldoorn bulbs were cooled at 9°C from 13 August 1991, planted in trays (see below) on 24 September and housed (18°C) on 14 January 1992.

The same eight materials used in narcissus experiment 2 were used, alone, alone but with a sand cover, or mixed with equal volumes of baled peat. Peat used was adjusted to pH 7.0 using 2.4 kg lime per m^3 per pH unit rise required (see 'Substrates' (below) and Table 6). Planting in trays was as described above for experiment 1, as were the methods of crop assessment.

Experiment 3 (pot-plant experiment) Tulip Lucky Strike bulbs were cooled at 9°C from 10 September 1991, potted (see below) and returned to 9°C on 23 October, and housed (18°C) on 9 January 1992.

The same six materials used in narcissus experiment 3 were used, expect that peat was adjusted to pH 7.0 using 2.4 kg lime per m^3 per pH unit rise required (see 'Substrates' (below) and Table 6). Five bulbs were planted in each 14 cm diameter half-pot, such that the bulb tip emerged at the top of the pot. Pots were watered well before cold storage and kept sufficently watered in storage. Half of the pots of each substrate was drenched with paclobultrazol solution, the remaining pots receieving a plain water drench as a control. Paclobutrazol (as 12.5 ml Bonzi diluted to 1 litre, 80 ml/pot) was applied on the day of housing (9 January), when mean shoot lengths for the different substrates were 9 to 13 cm.

The dates when half the flowers in a pot had reached a marketable stage (colouring buds), and when half had begun to senesce, were recorded, along with the lengths of all stems at these dates, which were used to produce pot mean lengths and shelf-lives. The number of viable flowers produced in each pot was also recorded.

Lily experiment

Plant material Bulbs of *Lilium* cultivars Connecticut King (grade 12/14 cm) and Star Gazer (grade 14/16 cm) were purchased as frozen bulbs and thawed overnight for planting on 31 March 1992.

Experimental methods Bulbs of lily cultivars Connecticut King and Star Gazer were planted in various substrates (see below) on 31 March 1992. General planting procedures followed those given for narcissus (see above), except that 27 bulbs were planted per tray for Connecticut King and 16 per tray for Star Gazer. Half the trays of each cultivar were moved to a glasshouse on the same day as planting, the other half after storage at 10°C for three weeks. Glasshouse minimum maintained temperature was 14°C with ventilation at 16°C.

The following substrates were used: baled peat, bulk peat, soil, coir, bark, coir mix, shredded glazed paper, sawdust, granular rockwool and chopped straw (see 'Substrates' (below) and Table 11 for details). Based on nutrient analysis (repeated to take account of possible batch-to-batch variation), substrates were amended as follows before use. Peat and the nutrient-free materials (paper, sawdust and rockwool) had a fertiliser (PG mix, containing 14:16:18 N:P:K and trace element) added at a rate of 1 kg per m^3. Other materials (soil, coir, bark, coir mix and straw) were amended with appropriate quantities of 'straight' fertilisers (sulphate of potash (45% K_2O), dicalcium phosphate (18% P_2O_5), diammonium phosphate (23% P_2O_5, 21% N) or ammonium nitrate (34% N)) to produce a nutrient level equivalent to that of the baled peat with PG mix. For acidic materials (peat, bark and sawdust), magnesian lime (as Dolodust) was added at a rate of 2.5 kg per m^3 per pH unit rise required to achieve a pH of 6.5. In addition, all substrates were amended with fitted trace elements (as 0.2 kg FN253A/m^3) and with etridiazole (as 0.18 kg Aaterra/m^3). After mixing (see below) and standing for 2 days, all substrates were re-analysed (Table 11). To correct for magnesium deficiency in deficient substrates not requiring the addition of lime (ie, coir, coir mix, paper and rockwool), solid magnesium sulphate was applied to the substrate surface after planting at a rate equivalent to 1.5 kg/m^3.

No routine liquid feeding was planned; however, very pale plants of cv Star Gazer, in rockwool, sawdust, paper and bark substrates, received a weekly liquid feed (containing 200 mg/l N) from 4 June 1992 onwards. Connecticut King plants were sprayed against aphids with pirimicarb (as 5 g Pirimor/10 litres, HV spray) on 4 June 1992.

During the trial, general aspects of crop appearance such as foliage colour, rooting, crop support, etc, were noted, and blooms were cropped daily each morning once the first floret had opened. The overall diameter of the first floret, overall plant height and length of any basal zone of dead leaves were measured, the number of viable and aborted buds counted, and any leaf scorch was scored (1 = no scorched leaves, 2 = less than five, 3 = five to ten, 4 = up to 50%, and 5, more than 50% of leaves affected). All stems producing at least one viable bud were recorded. Five representative blooms from each tray were assessed for vase-life, as described for narcissus and tulip except that the test room was run at 20°C.

Substrates

The substrates tested included a medium-grade baled sphagnum peat, regarded as the ADAS standard, along with proprietary materials and other locally obtained materials (for analyses see Tables 2, 6 and 11).

Proprietary materials used were:

1) bark (as Cambark 100, Camland Products Ltd),

2) coir (coconut fibre blocks, Hensby Biotech Ltd),

3) a coir/straw/manure mixture ('coir mix') (as a multipurpose horticultural compost with no added nutrients, Hensby Biotech Ltd),

4) granular rockwool (as Grodan granules, medium grade, Grodania AS) and

5) chopped straw (Samgran, Samgran Straw Ltd).

(Product names are given only for accurate reporting, and no criticism is intended of products not mentioned.)

The following locally obtained materials were used:

1) bulk peat (as lifted),

2) soil (a calcareous alluvial gley from HRI Kirton),

3) shredded glazed paper (office waste),

4) shredded unglazed paper (newspaper),

5) shredded used rockwool blocks (from a tomato grower),

6) softwood sawdust,

7) softwood shavings, and

8) chopped straw (free, as far as could be ascertained, of potentially harmful herbicide residues).

Substrates were dampened and mixed in a compost mixer (Universal Fabrications) run for a standard period (3 to 4 minutes).

Samples were taken from substrates before use to determine pH, nutrients (P, K, Mg, NO_3-N, NH_4-N and conductivity) and air-filled porosity (AFP), using standard ADAS techniques. Results of analyses are given in Tables 2, 6 and 11.

Statistical design and analysis

All experiments were of a randomised block design, with three replicate blocks, except for the pot-plant trial where four blocks were used. During cold storage, different substrates were not mixed in a stack of trays, to avoid any effects due to leaching. Data were subjected as appropriate to the analysis of variance.

RESULTS AND DISCUSSION

Narcissus

Analysis of substrates (Table 2) There was a wide range of pH, nutrient and AFP values for the substrates tested. Most, apart from AFP, were likely to be in a satisfactory range for narcissus.

pH values ranged from 4.5 to 8.1, the lowest being baled peat and the highest being soil. In some materials there was a complete absence or very low levels of available nutrients, such as baled peat, paper (both types) and granular rockwool. Materials such as coir mix and chopped straw (both types) contained considerable quantities of potassium, with conductivities of >300 μs (ADAS Index 2) which may inhibit the rooting of sensitive bulbs. Nitrogen contents of the substrates were generally very low, except for coir mix.

AFP values ranged from as little as 3.7% for soil, up to 72.9% for shredded glazed paper. Materials such as paper (both types), wood shavings and straw (both types) had unacceptably high AFP values. Bulk peat and soil had unacceptably low values. Very open substrates with high AFPs may require more frequent watering, whilst low AFPs would give rise to too much water retention and a limited air supply. The adverse effects of high AFP and high nutrient content were mitigated by mixing with 50 per cent peat. A covering of sand over some very open materials, such as paper and straw, may also reduce the effects of high AFP values.

Narcissus 'proprietary' materials experiment At housing, root development was poorer in soil and coir mix than in other substrates, but crop support was adequate in all cases.

Crop performance for the three rounds of narcissus Golden Harvest is shown in Table 3. In the first round, where cropping occurred over an extended period (15 to 16 days), there were no significant differences between substrates in cropping dates or cropping period (from 10 to 90% cropping). In later rounds, where cropping was rapid, crops in coir mix were about 2 days later to 50 and 100 per cent harvest dates than those in other substrates, and this extended the cropping period, significantly so in the case of the third round.

In no case were there significant differences in the total yield of marketable blooms, but there were differences in the average lengths of stems. In the first round, plants grown in soil had more shorter stems, with about equal yields in the 35-40 and 40-45 cm grades, whereas in the other substrates most blooms were in the 40-45 cm grade with an appreciable number in the 45-50 cm grade. In both second and third rounds, crops in coir mix were significantly shorter than others, with many in the 35-40 cm grade; the longest stems, with useful numbers in the 45-50 cm grade, occurred in crops grown in baled peat and coir. Crop losses due to unproductive bulbs (mainly late-flowering 'scrubs' but including occasional blind or shrivelling buds) averaged 2.1 per tray, with no obvious differences due to substrates. Flower quality appeared similar in all substrates. Vase-life was similar for all substrates within a forcing round, although extending slightly with later forcing (means of 5.5-6.0 days for the first round, 6.2 to 7.0 for the third).

In the first round, plants grown in soil had rooting systems which were clearly less well developed at housing than in other substrates; this, coupled with the low AFP of the soil (Table 2) and the long glasshouse phase, probably resulted in poor growth and fewer tall blooms. In later rounds, shorter stems in plants grown in coir mix may have been related to poorer root systems observed in this case, perhaps a result of high nutrient levels, especially K and N, in coir mix. Evidently the slower-growing early crop was able to cope with these higher nutrient levels, while a low AFP was acceptable in the less stressed later rounds.

<u>Narcissus 'waste' materials experiment</u> At housing, crops grown in paper (glazed or unglazed), sawdust and chopped straw (either type) were less developed than others, with shorter shoots and poorer root systems. Poorer root systems were still evident at the end of cropping in these materials, but crop support in all cases was acceptable.

The results of forcing are summarised in Table 4. Cropping dates and period (between 10 and 90% cropping) were similar to those of peat-grown crops when bulbs were forced in unglazed paper, sawdust, wood shavings or rockwool (either granular or shredded used blocks), but cropping was delayed (by a few to 10 days) by forcing in glazed paper or chopped straw (either type). There was, however, no delay of cropping when any of these substances were used in mixture with peat. The use of a sand cover with the materials which were unsatisfactory, designed to improve compaction and reduce water losses, did not enhance cropping.

Compared with peat, the number of marketable blooms was reduced (by up to 10%) when glazed paper, shredded rockwool blocks, or, especially chopped straw (either type) were used alone; using a sand cover prevented this loss to some extent. All other substrates and all mixtures (except unglazed paper plus peat) gave yields similar to those in peat. Mean stem length was reduced, with lower yields in grades >40 cm, in the following substrates : glazed paper (used alone or with sand cover), sawdust (used alone) and chopped straw (either type but only when used with a sand cover). Crop losses, amounting to an average of 1.7 blooms per tray, consisted of occasional 'scrubs', and were not obviously related to the substrate used. Flower quality was acceptable. Samples assessed for vase-life showed little variation: vase-life varied between 8.3 and 9.4 days for all substrates, except for straw used with a sand cover, where it fell to 7.1 and 7.8 for the two types of straw. Another aspect of flower quality, leaf sheath length, was markedly reduced in poorer substrates such as glazed paper or straw with sand.

Poor root growth in chopped straw and shredded paper was probably a result of poor root to substrate water contact in these materials with high AFP values, exacerbated in the chopped straw by high K levels (particularly in the proprietary material). Initial growth was also poor in sawdust, a material with similar analysis to the standard baled peat, but in this case cropping was not delayed. Cropping was reduced using shredded rockwool blocks, although the reasons for this were unclear. It was interesting to note that even the most unsatisfactory materials (glazed paper and straw) could be used to produce good crops when mixed with equal volumes of peat, although when used alone most aspects of performance were degraded. Of the non-peat substrates, coir, bark, coir mix, wood shavings and granular rockwool produced good and timely crops, despite, in some cases, high nutrient levels (coir mix) or high AFP values (wood shavings).

<u>Narcissus pot-plant experiment</u> The performance of pot-grown Golden Harvest is given in Table 5. There were no significant effects of either substrate or retardant on marketing date, shelf-life (marketing to senescence), or the number of viable flowers produced per pot. Measured at marketing stage, mean stem length was unaffected by substrate type, and in all substrates ethephon had retarded stem extension about equally. Measured at senescence, untreated crops in bark and sawdust were shorter than those in other substrates, although the effects of ethephon were still evident in all substrates. There is clearly potential for producing pot-grown narcissus (dwarfed if necessary) in a range of visually acceptable non-peat substrates.

Table 2. Analysis of substrates as used for narcissus experiments: pH, nutrients* and air-filled porosity (AFP)

Substrate	pH	P (mg/l)	K (mg/l)	Mg (mg/l)	Conductivity (μS)	NO_3-N (mg/l)	NH_4-N (mg/l)	AFP (%)
Peat (baled)	4.5	<1 (0)	4 (0)	<1 (0)	58 (0)	5 (0)	11 (0)	11.5
Peat (bulk)	4.9	1 (0)	24 (0)	20 (3)	179 (1)	7 (0)	<1 (0)	5.5
Coir	6.2	3 (0)	58 (2)	1 (0)	67 (0)	<1 (0)	<1 (0)	18.0
Bark	4.9	4 (0)	56 (2)	4 (0)	68 (0)	<1 (0)	<1 (0)	28.2
Coir mix	5.2	43 (6)	367 (5)	17 (3)	313 (2)	70 (3)	13 (0)	12.2
Soil	8.1	5 (1)	66 (2)	17 (3)	218 (1)	8 (0)	<1 (0)	3.7
Shredded glazed paper	7.0	<1 (0)	<1 (0)	<1 (0)	32 (0)	10 (0)	1 (0)	72.9
Shredded unglazed paper	6.3	<1 (0)	<1 (0)	<1 (0)	17 (0)	8 (0)	1 (0)	54.2
Sawdust	5.2	1 (0)	32 (1)	2 (0)	55 (0)	8 (0)	2 (0)	14.6
Wood shavings	5.4	1 (0)	26 (1)	<1 (0)	39 (0)	9 (0)	1 (0)	58.7
Rockwool (granular)	6.3	<1 (0)	2 (0)	3 (0)	25 (0)	8 (0)	3 (0)	26.3
Shredded used rockwool blocks	6.4	26 (4)	13 (0)	5 (0)	56 (0)	13 (0)	2 (0)	17.3
Chopped straw	6.1	5 (1)	314 (5)	14 (2)	214 (1)	6 (0)	<1 (0)	51.8
Chopped straw (proprietary	6.4	22 (4)	600 (6)	18 (2)	360 (2)	11 (0)	9 (0)	57.8
Peat + glazed paper	4.9	<1 (0)	6 (0)	2 (0)	65 (0)	9 (0)	5 (0)	13.3
Peat + unglazed paper	4.5	<1 (0)	1 (0)	<1 (0)	59 (0)	4 (0)	8 (0)	13.7
Peat + sawdust	5.0	<1 (0)	6 (0)	2 (0)	49 (0)	4 (0)	6 (0)	12.6
Peat + wood shavings	5.0	1 (0)	10 (0)	3 (0)	44 (0)	17 (1)	2 (0)	16.9
Peat + rockwool	6.3	<1 (0)	16 (0)	8 (1)	64 (0)	10 (0)	9 (0)	14.1
Peat + rockwool blocks	5.3	26 (4)	16 (0)	9 (1)	73 (0)	17 (1)	18 (0)	18.2
Peat + straw	5.0	1 (0)	144 (3)	12 (2)	138 (0)	4 (0)	1 (0)	26.2
Peat + proprietary straw	4.9	<1 (0)	202 (4)	3 (0)	161 (1)	8 (0)	10 (0)	27.4

*figures in parenthesis are ADAS indices

Table 3. Crop performance of narcissus Golden Harvest in the 'proprietary' materials experiment

Substrate	Cropping dates (days from 1 Jan) First	50%	Last	Days from 10% to 90% pick	Marketable blooms/ tray	Mean length (stem + bud, cm)	% blooms in length grades <30	30-45	35-40	40-45	45-50	>50
First round												
Peat (baled)	334	348	359	15.0	165.3	43.6	0	1	8	61	30	0
Coir	335	349	360	16.3	173.3	42.6	0	2	11	70	18	0
Bark	334	348	358	15.3	169.7	42.6	0	1	15	67	17	0
Coir mix	335	349	359	15.7	168.0	42.9	0	2	12	63	24	0
Peat (bulk)	335	349	359	16.0	172.3	42.3	0	1	17	67	15	0
Soil	335	349	358	15.0	167.3	39.9	1	4	45	46	4	0
SED (df=10)	0.8	1.0	1.4	1.19	7.94	0.42	-	-	4.9	3.6	3.8	-
Significance	NS	NS	NS	NS	NS	***	-	-	***	***	***	-
Second round												
Peat (baled)	10	12	19	4.0	168.7	44.0	0	2	11	49	33	6
Coir	10	13	17	3.3	169.0	44.9	0	0	6	44	45	5
Bark	10	12	17	4.0	169.7	43.4	0	1	11	59	29	1
Coir mix	11	15	20	4.7	169.7	40.4	3	7	29	49	12	1
Peat (bulk)	10	13	17	4.0	174.7	42.8	0	0	18	59	23	1
Soil	10	12	18	4.3	175.3	43.2	1	1	12	60	24	2
SED (df=10)	0.4	0.4	0.8	0.46	3.32	0.47	-	-	5.0	9.3	6.7	-
Significance	NS	***	*	NS	NS	***	-	-	*	NS	*	-
Third round												
Peat (baled)	28	30	35	3.0	170.7	42.5	1	1	17	59	22	0
Coir	28	29	34	2.7	172.0	42.9	0	2	15	55	27	0
Bark	28	30	35	3.0	168.3	41.4	1	2	28	59	11	0
Coir mix	29	32	37	5.3	170.0	38.3	6	10	45	33	5	0
Peat (bulk)	28	30	35	3.0	172.7	41.5	1	2	25	61	11	0
Soil	28	30	36	3.0	175.3	40.5	1	4	37	51	7	0
SED (df=10)	0.2	0.4	0.8	0.52	5.04	0.51	-	-	5.4	6.8	4.4	-
Significance	*	***	NS	**	NS	***	-	-	**	*	**	-

Statistical significance due to substrate indicated by NS (not significant) or *, ** and *** (significant at 5,1 or 0.1% probability levels; -, not appropriate to test

Table 4. Narcissus forced flower production in the 'waste' materials experiment

Substrate and mode of use		Cropping dates (days from 1 Jan)			Days from 10% to 90% pick	Marketable blooms/ tray	Mean length (stem + bud, cm)	% blooms in length grades					Vase-life (days)	Leaf sheath length (cm)
		First	50%	Last				<30	30-35	35-40	40-45	>45		
Peat (baled)	Alone	347	353	362	7.4	182.4	41.9	1	1	17	73	8	9.0	5.4
Shredded glazed paper	Alone	351	357	365	7.3	175.7	39.0	1	10	46	41	2	9.0	3.5
	+ sand cover	348	356	367	9.7	179.7	40.5	0	3	36	59	2	9.0	4.5
	+ 50% peat	346	353	361	7.3	183.7	42.0	0	1	18	71	10	8.3	5.5
Shredded unglazed paper	Alone	348	353	364	6.7	182.7	40.9	0	2	30	65	3	8.8	6.3
	+ sand cover	348	353	363	7.3	182.3	41.5	0	1	22	69	7	9.1	5.7
	+ 50% peat	348	353	362	7.3	168.3	42.0	0	1	19	69	11	9.2	5.2
Sawdust	Alone	348	353	361	7.3	183.0	40.2	1	2	44	53	2	8.7	5.2
	+ sand cover	346	353	362	7.0	178.0	42.4	0	1	16	67	16	8.6	5.6
	+ 50% peat	347	354	363	8.0	186.0	41.4	0	1	24	72	3	8.8	4.8
Wood shavings	Alone	346	353	363	7.7	183.7	40.9	0	1	33	62	4	8.3	4.9
	+ sand cover	348	354	364	7.7	182.3	41.1	0	1	31	63	5	8.4	5.5
	+ 50% peat	347	352	360	7.0	179.7	41.6	1	1	22	68	7	8.8	5.3
Rockwool (granular)	Alone	347	354	365	8.0	181.0	41.2	0	1	28	66	4	8.9	5.1
	+ sand cover	346	353	363	9.0	182.7	40.9	0	3	32	57	8	8.6	4.8
	+ 50% peat	346	353	361	7.7	187.3	41.8	0	1	22	65	11	8.3	5.0
Shredded used rockwool blocks	Alone	348	353	364	8.0	176.7	41.2	0	1	29	66	4	8.3	6.0
	+ sand cover	347	354	363	8.0	177.3	41.6	0	1	19	74	5	8.3	5.1
	+ 50% peat	347	352	361	7.0	182.3	42.1	0	1	15	75	9	9.4	5.8
Chopped straw	Alone	349	356	365	8.3	172.3	42.7	0	0	14	66	19	8.3	5.1
	+ sand cover	350	359	369	10.7	176.7	40.6	1	3	36	54	6	7.1	3.4
	+ 50% peat	347	354	363	8.0	182.0	42.2	0	1	17	68	14	8.7	5.7
Proprietary chopped straw	Alone	351	359	372	11.0	165.7	43.4	0	2	11	56	31	8.5	5.0
	+ sand cover	353	363	376	13.0	172.7	40.1	0	7	38	51	4	7.8	3.2
	+ 50% peat	347	353	365	7.3	185.0	41.6	0	2	20	72	6	8.5	5.0
	SED (df=54)	1.0	0.9	1.9	0.97	4.20	0.55	-	-	7.1	7.2	-	-	-
	Significance	***	***	***	***	***	***	-	-	***	***	-	-	-

For statistical significance, see footnote to Table 3

Table 5. Narcissus Golden Harvest performance in the pot-plant experiment

Substrate	Ethephon treatment*	Market date (days from 1 Jan)	Plant height (cm) Market stage	Senescence	Viable buds/pot	Shelf-life (days)
Peat (baled)	+	9.0	29.4	42.3	9.0	18.3
	-	9.5	37.4	55.8	9.3	16.8
Coir	+	9.5	23.4	40.0	8.0	19.0
	-	9.0	37.0	58.0	9.3	17.0
Bark	+	10.0	27.6	41.0	9.0	18.5
	-	10.0	34.7	49.2	8.8	13.8
Soil	+	9.0	23.7	44.5	9.3	15.8
	-	9.8	35.0	56.3	8.5	17.0
Sawdust	+	10.3	23.0	40.7	9.5	17.5
	-	9.5	35.9	51.8	8.3	15.5
	SED (df=27)	0.87	2.73	2.14	0.71	1.98
	Significance (substrate)	NS	NS	**	NS	NS
	(retardant)	NS	***	***	NS	NS
	(interaction)	NS	NS	*	NS	NS

* mean shoot lengths at ethephon treatment for the five substrates were 13, 13, 10, 11 and 11 cm, respectively.
For statistical significance, see footnote to Table 3

Tulip

Analysis of substrates (Table 6) There was a wide range of pH, nutrient and AFP values for the substrates tested. pH, conductivity and AFP values may be outside the range acceptable for tulip forcing.

Substrate pH ranged from 4.9 to 8.1, and peats were limed to pH >7. Some of the unamended substrates with pH <6.5 may be unsuitable for tulips. In some materials, there was a complete absence or very low levels of available nutrients, such as baled peat, paper (both types) and granular rockwool. Materials such as coir mix and chopped straw (both types) contained considerable quantities of potassium with conductivities of >300 μs (ADAS Index 2), which may inhibit the rooting of sensitive bulbs. Nitrogen contents of the substrates were generally very low, except for coir mix.

AFP values ranged from as little as 3.7% for soil, up to 72.9% for shredded glazed paper. Materials such as paper (both types), wood shavings and straw (both types) had unacceptably high AFP values. Bulk peat and soil had unacceptably low values. Very open substrates with high AFPs may require more frequent watering, whilst low AFPs would give rise to too much water retention and a limited air supply.

The adverse effects of low pH, high AFP and high nutrient content were mitigated on mixing with 50 per cent peat. A covering of sand over some very open materials such as paper and straw may also reduce the effects of high AFP values.

Tulip 'proprietary' materials experiment Rooting in other substrates was generally at least as good as in peat. Assessed at housing, however, root growth was poorer in soil in the third round of Paul Richter and in the second and third rounds of Apeldoorn. After cropping, crops in some trays of coir mix, bark and soil had relatively poor roots compared with peat. There were, however, no problems with crops lodging.

Occasional shoots were infected with *Penicillium* sp., but numbers were significant only in the third round of Apeldoorn; in this case, the numbers of affected shoots averaged 1 per tray for coir and bark and 5 per tray for peat, but 11 per tray for coir mix and soil.

Results for the three rounds of cultivars Paul Richter and Apeldoorn are given in Tables 7 and 8, respectively. Differences in cropping dates were slight or non-significant, while there were no significant differences in cropping period. In respect of total yields or yields of blooms in different length grades, however, there was less agreement between the results of the three forcing rounds than in the case of the narcissus experiment. The two cultivars also responded differently.

The early round of Paul Richter showed high tray-to-tray variation in yields, and consequently differences, although appearing large, were sometimes not statistically significant. Baled peat gave the highest yields, and coir, bark and coir mix the lowest. In the second round, baled peat and coir gave the lowest yields, and, in the third round, coir mix and soil. In both the first and third rounds, coir mix, bulk peat and soil consistently produced short stems, with many in the 30-35 cm grade, rather than the majority in the 35-40 cm grade as for crops grown in baled peat, coir and bark. In the second round, however, bark produced relatively tall crops, soil shorter crops, and the other four substrates gave similar results. Crop losses in Paul Richter were due bud blasting and the rejection of occasional flowers in earlier rounds due to green perianth tips or tied leaf. Vase-life was similar, within a forcing round, for cut-flowers from each substrate.

The first round of Apeldoorn was seriously affected by floral bud blasting, although many more marketable blooms were obtained in soil-grown crops than in others. Bark produced many very short (25-30 cm) stems, and stems were also shorter than average in the case of bulk peat. Yields from the second and third rounds were generally satisfactory. In the second round, bark resulted in a low yield of very short (<30 cm) stems, whereas the results in other substrates were similar. In the third round, yields from bulbs grown in coir mix were highest, while soil (but not bark) gave shorter stems. Crop losses were due largely to bud blasting, although occasional flowers were rejected due to white-tipped petals or tied leaf. On the basis of the samples taken, vase-life was similar for different substrates, within a forcing round.

The responses of tulips to growing in different substrates were less easily understood than in the case of narcissus, no doubt reflecting the greater sensitivity of tulips to adverse conditions. There were instances of poorer rooting, compared with baled peat, in soil (due to low AFP), coir mix (high nutrients) and bark (high AFP). Rooting was more generally satisfactory in peat and coir, despite the conductivity and low AFP of the former and the relatively high conductivity of coir. Using different substrates did not affect cropping dates in either cultivar, but there were major effects on numbers and grade of marketable flowers.

Given the undesirable characteristics (conductivities or AFP values) of many of the alternatives used in this experiment, it would be difficult to make firm conclusions unless the responses to these factors of slow-growing, relatively stressed early-forced crops, and of un-stressed, fast-growing late-forced crops, were better understood. For Paul Richter, a good quality peat would be recommended for all rounds (it is difficult to explain the poor results of using baled peat in the second round of the trial). For Apeldoorn, a cultivar somewhat prone to bud blasting when using warm-stored, early-forced bulbs, only soil gave good yields in the first round; for later rounds, peat, coir or coir mix gave good results. The survival of flower buds in the early round grown in soil may have been connected with the initially slower growth of these plants.

Tulip 'waste' materials experiment At housing, crops grown in the following substrates had poor root systems and short shoots, compared with peat-grown bulbs: paper (glazed or unglazed), sawdust, wood shavings, and straw (either type). Assessed at the end of cropping, only bulbs in shredded rockwool (alone or plus peat) were judged to have root systems as extensive as those in peat; nevertheless, crop lodging did not occur to any serious extent.

Forcing results are given in Table 9. Compared with the relatively uniform responses of narcissus, major differences in performance were seen in these substrates. The most pronounced effects of substrate on cropping applied to first and 50 per cent cropping dates. Delays of about 2 days to 50 per cent cropping occurred using shredded paper (either type), sawdust, wood shavings, wood shavings plus peat, and rockwool (granular or shredded blocks), but with straw larger delays were produced (up to 8 days) whether the materials were used alone or mixed with peat. The dates of final cropping were generally similar to those in peat, although in straw or straw plus peat the completion of picking was also delayed (by up to 5 days). Cropping periods (days from 10 to 90 per cent pick) were generally similar to that of peat, but were extended by about 2 days in some cases (glazed paper plus peat, wood shavings plus peat, and chopped straw).

With respect to the number of marketable blooms cropped, substrates fell into three groups. First, yields broadly comparable with those in peat were obtained using unglazed paper plus peat, rockwool (both types), and chopped straw (except when a sand covering was added). Secondly, much reduced yields were obtained using glazed paper plus peat, sawdust plus peat, and wood shavings (alone or plus peat, but not with a sand covering). Thirdly, negligible numbers of flowers were cropped from paper (either type, with or without sand cover), sawdust (with or without sand cover), and wood shavings and straw with a sand cover. Crop losses were due almost entirely to flower blasting occurring at a late stage, although very occasional blooms were unmarketable due to white petal tips. The lengths of marketable blooms were relatively uniform (although where very few blooms were cropped from a substrate means will be unreliable); in no case did substrates giving good yields of blooms result in reduced stem length, compared with peat. For all substrates which gave more than a negligible number of marketable flowers, vase-life was tested and was between 6 and 7 days in all cases, except for proprietary chopped straw (5 days).

Ignoring minor delays in cropping, the following substrates gave satisfactory yields in this trial, similar to those in peat: unglazed paper with peat, and rockwool (granular or shredded used blocks, alone or with peat). These alternatives have low or only moderate conductivities, moderate AFP values, and slightly acidic pH values; other materials with similar characteristics must be unsuitable because of other constituents. For tulips, the use of a sand covering under these conditions led to capping, with no benefit to cropping.

<u>Tulip pot-plant experiment</u> Table 10 summarises the performance of pot-grown Lucky Strike. At housing, tulip bulbs in sawdust were pushing out of the substrate due to root growth and inadequate anchorage. Market and senescence dates were the same in all treatments. Plants height (at market stage and senescence) was shorter in bark and soil than in other substrates. Paclobutrazol effectively retarded stem extension in all substrates except sawdust, where it was ineffective. Growing in sawdust also reduced the number of viable buds.

Table 6. Analysis of substrates as used for tulip experiments: pH, nutrients* and air-filled porosity (AFP)

Substrate	pH	P (mg/l)	K (mg/l)	Mg (mg/l)	Conductivity (μS)	NO_3-N (mg/l)	NH_4-N (mg/l)	AFP (%)
Peat (baled)	7.1	<1 (0)	7 (0)	15 (2)	112 (0)	17 (1)	18 (0)	11.5
Peat (bulk)	7.4	<1 (0)	22 (0)	12 (1)	214 (1)	6 (0)	<1 (0)	5.5
Coir	6.2	3 (0)	58 (2)	1 (0)	67 (0)	<1 (0)	<1 (0)	18.0
Bark	4.9	4 (0)	56 (2)	4 (0)	68 (0)	<1 (0)	<1 (0)	28.2
Coir mix	5.2	43 (6)	367 (5)	17 (3)	313 (2)	70 (3)	13 (0)	12.2
Soil	8.1	5 (1)	66 (2)	17 (3)	218 (1)	8 (0)	<1 (0)	3.7
Shredded glazed paper	7.0	<1 (0)	<1 (0)	<1 (0)	32 (0)	10 (0)	1 (0)	72.9
Shredded unglazed paper	6.3	<1 (0)	<1 (0)	<1 (0)	17 (0)	8 (0)	1 (0)	54.2
Sawdust	5.2	1 (0)	32 (1)	2 (0)	55 (0)	8 (0)	2 (0)	14.6
Wood shavings	5.4	1 (0)	26 (1)	<1 (0)	39 (0)	9 (0)	1 (0)	58.7
Rockwool (granular)	6.3	<1 (0)	2 (0)	3 (0)	25 (0)	8 (0)	3 (0)	26.3
Shredded used rockwool blocks	6.4	26 (4)	13 (0)	5 (0)	56 (0)	13 (0)	2 (0)	17.3
Chopped straw	6.1	5 (1)	314 (5)	14 (2)	214 (1)	6 (0)	<1 (0)	51.8
Chopped straw (proprietary)	6.4	22 (4)	600 (6)	18 (3)	360 (2)	11 (0)	9 (0)	57.8
Peat + glazed paper	7.6	<1 (0)	26 (0)	15 (2)	166 (1)	3 (0)	7 (0)	13.3
Peat + unglazed paper	7.2	<1 (0)	13 (0)	9 (1)	107 (0)	2 (0)	1 (0)	13.7
Peat + sawdust	7.0	<1 (0)	16 (0)	8 (1)	87 (0)	9 (0)	2 (0)	12.6
Peat + wood shavings	7.3	<1 (0)	18 (0)	14 (2)	88 (0)	8 (0)	1 (0)	16.9
Peat + rockwool	7.5	<1 (0)	10 (0)	11 (2)	100 (0)	15 (0)	3 (0)	14.1
Peat + rockwool blocks	7.2	10 (2)	19 (0)	12 (2)	113 (0)	22 (1)	9 (0)	18.2
Peat + straw	7.1	<1 (0)	240 (4)	15 (2)	213 (1)	13 (0)	1 (0)	26.2
Peat + proprietary straw	7.4	<1 (0)	300 (5)	12 (2)	220 (1)	1 (0)	1 (0)	27.4

*Figures in parenthesis are ADAS indices

Table 7. Crop performance of tulip Paul Richter in the 'proprietary' materials experiment

Substrate	Cropping dates (days from 1 Jan) First	50%	Last	Days from 10% to 90% pick	Marketable blooms/ tray	Mean length (stem + bud, cm)	% blooms in length grades <30	30-35	35-40	>40
First round										
Peat (baled)	4	6	9	3.3	45.7	36.5	0	27	66	7
Coir	5	7	9	3.3	28.7	37.1	0	19	70	11
Bark	4	6	9	2.7	25.7	36.2	8	15	72	6
Coir mix	5	7	10	3.3	25.7	34.6	2	53	45	0
Peat (bulk)	3	5	9	3.0	34.0	35.3	3	40	54	3
Soil	5	7	10	3.7	37.3	34.3	8	49	41	2
SED (df=10)	0.7	0.7	0.7	0.59	9.48	1.04	5.9	8.7	10.7	6.0
Significance	NS	*	NS	NS	NS	NS	NS	**	NS	NS
Second round										
Peat (baled)	22	23	26	3.3	47.0	37.0	1	23	61	15
Coir	21	23	26	3.0	47.3	37.6	1	22	50	27
Bark	21	23	26	2.7	57.3	38.7	1	5	63	31
Coir mix	22	23	26	2.7	59.3	36.9	0	26	61	13
Peat (bulk)	21	23	25	3.3	60.0	36.6	1	27	61	11
Soil	21	23	25	2.7	59.3	35.2	2	48	45	6
SED (df=10)	0.3	-	0.4	0.46	3.06	0.93	-	9.4	10.7	8.7
Significance	NS	-	NS	NS	**	NS	-	*	NS	NS
Third round										
Peat (baled)	25	27	30	2.3	62.7	36.4	1	23	72	4
Coir	25	27	29	2.3	60.3	36.9	0	18	76	6
Bark	25	27	30	2.3	60.0	36.3	1	26	71	3
Coir mix	25	28	30	2.7	56.7	33.4	9	65	27	0
Peat (bulk)	25	27	29	2.3	62.7	35.0	3	46	51	1
Soil	24	26	29	2.7	57.3	34.7	6	46	47	1
SED (df=10)	0.6	0.4	0.4	0.49	2.85	0.51	2.9	5.6	6.9	2.0
Significance	NS	*	NS	NS	NS	***	NS	***	***	NS

For statistical significance, see footnote to Table 3

Table 8. Crop performance of tulip Apeldoorn in the 'proprietary' materials experiment

Substrate	Cropping dates (days from 1 Jan) First	50%	Last	Days from 10% to 90% pick	Marketable blooms/ tray	Mean length (stem + bud, cm)	% blooms in length grades <25	25-30	30-35	35-40	40-45	>45
First round												
Peat (baled)	22	25	28	4.0	9.0	43.1	0	0	3	19	41	37
Coir	23	25	30	4.7	12.3	41.8	0	0	4	31	40	25
Bark	24	26	30	2.8	5.7	38.2	0	25	6	9	52	9
Coir mix	23	25	29	5.3	12.3	39.5	0	0	22	23	48	7
Peat (bulk)	25	26	29	1.7	4.0	37.6	0	0	50	14	19	17
Soil	21	24	29	5.3	39.0	42.3	0	0	6	13	60	21
SED (df=10)	1.1	0.7	1.6	1.17	6.11	1.64	-	-	-	10.8	12.9	13.1
Significance	*	NS	NS	NS	**	*	-	-	-	NS	NS	NS
Second Round												
Peat (baled)	30	34	37	5.0	45.0	37.7	0	4	24	40	30	2
Coir	30	35	39	3.3	48.0	37.1	2	5	21	47	25	1
Bark	32	36	39	4.3	29.7	30.2	20	35	18	20	7	0
Coir mix	30	34	37	4.0	47.7	38.0	0	3	16	51	30	1
Peat (bulk)	31	35	38	3.7	51.0	35.9	2	12	24	42	19	1
Soil	32	35	38	2.0	53.0	36.8	3	4	24	44	24	1
SED (df=10)	0.7	0.7	0.4	0.90	8.19	1.99	-	8.7	9.3	9.5	12.0	-
Significance	*	NS	**	NS	NS	*	-	*	NS	NS	NS	-
Third round												
Peat (baled)	50	53	57	3.3	49.3	36.9	0	5	21	56	18	1
Coir	50	53	57	3.3	52.7	38.8	0	1	13	47	36	3
Bark	50	53	57	4.3	49.0	38.8	0	3	12	49	32	5
Coir mix	50	53	56	3.3	65.7	38.2	0	2	18	47	31	2
Peat (bulk)	50	53	56	2.7	59.7	39.6	0	1	9	44	41	6
Soil	51	53	56	2.7	46.7	35.1	1	15	30	39	15	0
SED (df=10)	0.6	-	0.6	0.69	3.37	0.80	-	-	5.0	8.6	6.5	-
Significance	NS	-	NS	NS	**	**	-	-	*	NS	*	-

For statistical significance, see footnote to Table 3

Table 9. Tulip Apeldoorn forced flower production in the 'waste' materials experiment

Substrate and mode of use		Cropping dates (days from 1 Jan) First	50%	Last	Days from 10% to 90% pick	Marketable blooms/ tray	Mean length (stem + bud, cm)	% blooms in length grades <20	20-25	25-30	30-35	35-40	40-45	>45
Peat (baled)	Alone	30	34	38	4.0	44.7	40.4	0	0	1	12	29	46	12
Shredded glazed paper	Alone	37	37	37	0	0.1	30.2	0	1	50	49	0	1	1
	+ sand cover	33	36	39	3.8	0	36.6	1	3	11	22	34	24	6
	+ 50% peat	31	35	38	5.7	12.0	37.9	0	0	8	28	23	31	10
Shredded unglazed paper	Alone	36	36	36	1.0	1.0	36.8	1	1	0	5	93	0	0
	+ sand cover	33	36	39	3.8	0	36.6	1	3	11	22	34	24	6
	+ 50% peat	32	35	40	4.3	44.0	39.5	0	0	5	6	39	43	7
Sawdust	Alone	33	36	39	3.8	0	36.6	1	3	11	22	34	24	6
	+ sand cover	35	35	35	0	0.3	33.5	0	0	1	94	0	5	4
	+ 50% peat	32	35	38	4.7	12.3	37.0	0	0	4	18	63	13	2
Wood shavings	Alone	32	35	38	3.7	28.0	36.2	0	2	7	31	40	17	4
	+ sand cover	33	36	39	3.8	0	36.6	1	3	11	22	34	24	6
	+ 50% peat	32	36	40	5.7	24.7	36.3	2	3	10	19	44	18	5
Rockwool (granular)	Alone	32	36	39	4.3	50.7	40.2	0	0	0	10	35	45	10
	+ sand cover	31	34	38	4.0	41.3	40.6	0	0	0	6	39	41	14
	+ 50% peat	31	34	38	4.0	48.0	38.0	0	1	3	20	45	24	8
Shredded used rockwool blocks	Alone	32	36	39	4.7	36.0	40.6	0	0	0	11	32	43	15
	+ sand cover	31	35	38	3.7	50.7	39.4	0	0	2	8	45	39	6
	+ 50% peat	31	33	37	4.3	48.0	41.1	0	0	0	3	35	49	13
Chopped straw	Alone	34	38	42	5.7	34.0	35.6	1	3	20	27	32	14	4
	+ sand cover	39	39	43	3.6	2.0	27.0	0	25	49	28	2	0	0
	+ 50% peat	33	36	40	4.0	52.0	39.3	0	0	3	14	38	36	9
Proprietary chopped straw	Alone	35	39	43	4.3	56.7	36.1	0	1	8	31	40	20	1
	+ sand cover	40	42	43	3.3	7.0	26.1	13	22	50	12	3	0	0
	+ 50% peat	33	36	40	4.7	32.3	37.4	0	0	6	23	43	22	6
	SED (df=54)	0.8	0.6	0.9	0.75	-	1.74	-	-	-	-	-	-	-
	Significance	***	***	***	***	-	***	-	-	-	-	-	-	-

For statistical significance, see footnote to Table 3

Table 10. Tulip Lucky Strike performance in the pot-plant experiment

Substrate	Paclobutrazol treatment*	Plant height (cm) Market stage	Senescence	Viable buds/plot
Peat (baled)	+	18.2	26.2	5.0
	-	34.3	44.8	4.5
Coir	+	22.8	29.1	5.0
	-	29.9	31.9	4.8
Bark	+	17.5	28.3	5.0
	-	28.9	35.1	5.0
Soil	+	14.9	21.6	5.0
	-	32.4	43.1	5.0
Sawdust	+	29.5	38.2	4.5
	-	30.0	38.5	4.0
SED (df=27)		2.53	2.78	0.25
Significance	(substrate)	**	**	***
	(retardant)	***	***	*
	(interaction)	***	***	NS

* mean shoot lengths at paclobutrazol treatment for the five treatments were 11, 13, 9, 9 and 11 cm, respectively.
For statistical significance, see footnote to Table 3

Lily

Analysis of substrates Table 11 shows the analysis of substrates amended with either PG-mix or straight fertilisers (see Materials and Methods) and lime for peat substrates.

Substrate pH varied from pH 4.5 with limed baled peat, to pH 8 with soil. The low pH with limed peat may be a result of the material being analysed within 2 days of mixing. Soil, shredded glazed paper and both rockwool materials had high pH values likely to lock up trace elements such as iron and manganese.

Appropriate quantities of PG-mix or straight fertilisers had been added in an attempt to achieve equivalent nutrient status, but nutrients had disappeared from the shredded glazed paper. This may be because of mixing difficulties or absorption.

Substrate phosphorus levels ranged from 21 (ADAS Index 4) to 50 mg/litre (ADAS Index 6). There were large differences in potassium content, ranging from 31 (ADAS Index 1) to 588 mg/litre (ADAS Index 6). Magnesium levels were low in unlimed substrates such as coir, coir mix, shredded glazed paper and granular rockwool. Magnesium sulphate at a rate of 50 gram per tray (1.5 kg/m^3) was applied over the surface of the trays for these substrates. Conductivity levels were mostly index 0, with only bulk peat (Index 2) and chopped straw (Index 3) being at a level likely to affect the growth of sensitive bulbs.

Available nitrogen levels (nitrate-N + ammonium-N) were all at satisfactory levels, except in the shredded glazed paper. Levels may fall due to absorption in coir, paper, bark and sawdust during use.

AFP values for the substrates are given in Table 2. The straw and glazed paper are excessively open, with high AFP values. The soil and bulk peat had unacceptably low values.

Most substrates would have acceptable analysis for lily bulbs, except those with low pH, high conductivity or high AFP. There may also be some problems with nutrient lock-up during the growing season, which a single analysis cannot show.

Connecticut King Although crop support was adequate in all substrates tested, the development of the root systems was judged equivalent to that in standard peat only in the case of bark. Foliage was pale in the following substrates: rockwool, sawdust, paper, straw, and, especially, bark. Leaf samples analysed for nitrogen showed levels of 3.5 per cent in dark green leaves from the standard peat substrate, but only 2.0 per cent in pale leaves from bark-grown plants. Leaf scorch was marked in plants raised in coir and coir mix, but only when an additional cold treatment was applied. Plants in the poorer treatments had marked purple coloration on the stems. Most substrates remained essentially weed-free during glasshouse culture, but weed cover developed to a mean of 28 per cent with soil and 8 per cent with bulk peat. In straw-grown crops, the underside of lower leaves became disfigured by a black saprophytic mould.

Flower production for Connecticut King is shown in Table 12. Compared with peat, cropping dates were delayed by a few days to a week using soil, paper, rockwool and straw. There was, however, relatively little effect of substrate used on the length of the cropping period (days from 10 to 90% picking). Giving a three-week cold treatment before housing, compared with housing bulbs immediately after planting, delayed cropping by about 10 days and slightly reduced the cropping period.

There were no significant effects of either substrate or temperature treatment on the number of blooms produced per tray. There were a few non-productive bulbs (10 over the whole trial) or stems with aborted florets only (18 over the trial), these being balanced by occasional bulbs producing two stems. Seven of the stems with all florets aborted, however, occurred using soil as the substrate.

Overall plant height was shorter than with baled peat in all other substrates (including bulk peat). The restriction was especially strong using soil, paper, rockwool and straw, in the worst case, with soil, height reductions approached 40 per cent. Plants which received an additional cold treatment were a few cm taller than others, the interaction between substrate and temperature factors being non-significant. The basal part of the stem bearing dead leaves averaged only about 2 per cent of the overall height using standard peat, and increased significantly when bulk peat, bark, and especially soil and straw were used; the maximum dead leaf zone was seen in crops raised in soil (7 to 8% of total height). There was a slight but significant (1%) increase in the length of this zone when an additional cold treatment was given.

Flower size (measured as first floret diameter) was reduced somewhat using bark, paper, sawdust, rockwool and straw, and, more strongly, using soil. The number of viable buds per stem was reduced slightly using bark, paper, rockwool and sawdust, and more so when soil was used, when about 40 per cent of the buds were aborted. Cold treatment had little effect on floret size or number. Vase-life averaged 9.8 and 8.6 days in the standard and bulk peat substrates, and ranged from 7.3 to 9.2 days in other substrates: lowest vase-lives occurred in soil (7.3 days) and coir (7.6 days).

Star Gazer Crop support in all substrates was adequate but the consistently best developed root systems were seen in peat-raised crops. Foliage colour was pale, with a severely mottled appearance, when paper, sawdust, rockwool, bark and straw were used. Leaf samples analysed for N(%), Mg(%) and Mn(mg/kg) showed levels of 3.8, 1.0 and 73, respectively, in dark green leaves from peat-grown plants and 3.0, 0.2 and 21 in pale leaves of plants from straw. Treatments producing pale plants were given liquid feed weekly (see materials and methods), although with little indication of success. Leaf scorch in Star Gazer was insignificant (Table 13). For notes on weeds and saprophytic mould, the comments under Connecticut King apply.

Aspects of flower production are summarised in Table 13. Compared with peat, cropping was delayed by 2 to 3 days in some substrates, particularly soil, paper, rockwool and straw. There was a larger delay in picking the last blooms in paper and straw resulting in a longer cropping period in these cases, although, overall, effects of substrate on cropping period were not significant. Giving a 3-week cold treatment prior to housing delayed cropping by about a week, but the effects of substrate and temperature treatment did not interact significantly.

There were no significant effects of either substrate or temperature treatment on the number of blooms produced per tray, and very occasional non-productive bulbs (a total of five in the trial) were balanced by occasional bulbs producing double stems.

Overall plant height was reduced, compared with plants grown in peat, using soil, paper, sawdust, rockwool and straw; in the worst instance, there was a reduction of 22 per cent. Plants given an additional cold treatment at housing were consistently a few cm taller than those housed immediately after planting. The basal portion of the stem bearing dead leaves averaged, overall, 9 per cent of overall height, and was increased when grown in soil, bark, sawdust, rockwool, straw and, particularly, paper (where it increased to 18 per cent of height). The length of this zone was not significantly affected by cold treatment.

Flower size (first floret diameter) was reduced markedly when the crop was grown in paper, and to a lesser extent in soil, bark and straw. The number of viable buds per stem was slightly reduced in some cases, particularly using straw, but few aborted buds were produced by this cultivar so that differences were not statistically significant. Giving an additional cold treatment slightly reduced floret numbers. Mean vase-life varied between 6.9 and 8.1 days in all treatments, and was not reduced (compared with peat-raised plants) by substrates which reduced other aspects of performance.

General comments Despite the different habit of the two cultivars used, their responses to substrates were similar. Peat, coir and coir mix gave the most acceptable forcing results. In the case of Connecticut King bulbs, leaf tip scorch increased when coir or coir mix were used, but only following additional cold storage treatment which also slightly downgraded some other aspects of crop performance. Bark and sawdust showed promise for lily forcing: appropriate liquid feeding would be needed to remedy the pale foliage and inhibit the development of the dead leaf zone, a factor which appears stress-related. Pale foliage in bark, sawdust, paper and straw could be due to absorption of nutrients by the substrates. Pale growth in the case of rockwool could have been caused by leaching. The other substrates tested, soil, paper, rockwool and straw, all had high pH values (7.4 to 8.0), and it may be presumed that they would be suitable substrates for box forcing of lilies used in a mixture with peat or coir.

Table 11. Nutrient analysis of substrates as used for lily experiment*

Substrate	pH	P (mg/l)	K (mg/l)	Mg (mg/l)	Conductivity (µS)	NO_3-N (mg/l)	NH_4-N (mg/l)
Peat (baled)	4.5	21 (4)	31 (1)	13 (2)	120 (0)	20 (1)	25 (1)
Peat (bulk)	5.5	43 (6)	111 (3)	42 (5)	325 (2)	46 (2)	45 (1)
Coir	6.0	40 (5)	135 (3)	1 (0)**	173 (1)	25 (1)	19 (0)
Bark	5.5	38 (5)	104 (3)	17 (3)	160 (1)	31 (2)	18 (0)
Coir mix	5.9	50 (6)	157 (3)	1 (0)**	193 (1)	38 (2)	29 (1)
Soil	8.0	23 (4)	81 (2)	13 (2)	195 (1)	45 (2)	24 (1)
Shredded glazed paper	7.4	4 (0)	38 (1)	4 (0)**	136 (0)	7 (0)	13 (0)
Sawdust	5.5	42 (6)	130 (3)	18 (3)	195 (1)	34 (2)	27 (1)
Rockwool (granular)	7.5	33 (5)	89 (2)	6 (1)**	171 (1)	25 (1)	48 (1)
Chopped straw	7.4	31 (5)	588 (6)	15 (2)	406 (3)	19 (1)	35 (1)

*Figures in parenthesis are ADAS indices
**Magnesium sulphate added to surface of trays at planting

Table 12. Lily Connecticut King flower production in a range of substrates

Substrate and treatment	Cropping dates (days from 1 Jan) First	50%	Last	Days from 10% to 90% pick	Blooms /tray	Overall height (cm)	Dead leaf zone (% of height)	First floret diam (cm)	Viable buds /stem	Aborted buds (% of total)	Leaf scorch score
Plus cold treatment											
Peat (baled)	162	166	169	5.3	26.3	82.7	2.0	15.8	9.5	16.5	1.0
Peat (bulk)	164	166	171	4.0	26.7	74.5	4.4	15.4	9.0	17.6	1.0
Soil	165	168	175	7.0	25.3	51.8	8.4	12.0	6.6	36.2	1.0
Coir	164	166	172	4.0	27.0	75.1	2.6	16.0	9.2	15.3	1.6
Bark	163	166	169	3.7	26.7	76.5	5.1	15.0	8.6	20.5	1.0
Coir mix	164	167	170	5.0	26.7	74.8	2.2	15.9	9.7	12.8	1.5
Paper	166	168	176	5.0	26.7	62.3	3.7	13.8	8.2	27.9	1.0
Sawdust	164	167	171	4.7	27.0	72.3	3.1	14.9	8.9	19.4	1.1
Rockwool	165	170	176	7.0	26.0	65.9	1.7	15.0	8.4	22.9	1.2
Straw	165	168	175	6.7	28.7	67.0	5.8	14.9	7.7	29.1	1.0
Standard treatment											
Peat (baled)	152	156	161	6.0	27.0	77.6	1.8	15.8	10.1	13.6	1.0
Peat (bulk)	153	156	163	7.3	27.0	67.8	4.2	15.3	8.8	21.1	1.0
Soil	154	159	169	9.0	26.3	47.1	7.0	13.0	5.8	44.4	1.0
Coir	153	157	164	6.3	26.3	67.8	2.5	15.6	9.3	17.1	1.1
Bark	153	156	163	7.3	26.7	70.2	3.5	15.2	8.5	20.7	1.0
Coir mix	153	157	164	7.7	27.0	67.2	1.2	15.5	9.9	13.9	1.1
Paper	155	158	163	6.3	27.7	55.5	2.4	14.0	8.9	24.7	1.0
Sawdust	154	157	163	6.3	26.7	64.3	1.8	14.8	9.3	19.6	1.0
Rockwool	156	161	165	6.7	26.7	58.3	2.3	14.5	8.7	21.8	1.0
Straw	155	160	166	7.7	27.0	60.8	4.7	14.8	8.2	25.3	1.0
SED (df=38)	0.8	0.7	2.0	1.09	1.08	2.50	0.99	0.27	0.48	3.50	0.04
Significance											
(substrate)	***	***	***	*	NS	***	***	***	***	***	***
(treatment)	***	***	***	***	NS	***	*	NS	NS	NS	***
(interaction)	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	***

For statistical significance, see footnote to Table 3

Table 13. Lily Star Gazer flower production in a range of substrates

Substrate and treatment	Cropping dates (days from 1 Jan) First	50%	Last	Days from 10% to 90% pick	Blooms /tray	Overall height (cm)	Dead leaf zone (% of height)	First floret diam (cm)	Viable buds stem	Aborted buds (% of total)	Leaf scorch score
Plus cold treatment											
Peat (baled)	188	190	193	3.7	16.0	74.9	10.5	21.0	5.0	0.4	1.0
Peat (bulk)	187	191	193	5.3	16.3	71.1	11.8	20.4	4.8	0.4	1.0
Soil	190	192	196	3.3	16.3	61.0	15.7	19.7	4.5	2.2	1.0
Coir	189	192	193	2.7	16.3	74.2	12.2	21.5	4.8	1.6	1.1
Bark	187	190	192	3.3	17.0	75.5	13.8	20.3	4.8	1.7	1.0
Coir mix	188	191	194	4.3	17.0	72.0	11.9	21.2	4.5	2.1	1.2
Paper	190	193	199	5.0	16.0	63.8	18.1	17.9	4.6	1.3	1.1
Sawdust	189	191	194	3.0	16.7	69.9	14.6	20.5	4.6	1.7	1.1
Rockwool	190	192	195	3.3	17.0	68.4	12.2	20.3	4.4	3.8	1.0
Straw	190	193	200	7.3	16.3	65.1	13.2	19.6	4.2	3.3	1.0
Standard treatment											
Peat (baled)	180	182	186	3.7	16.3	69.2	8.8	20.1	4.9	0.4	1.0
Peat (bulk)	180	182	185	3.3	16.0	69.6	12.0	19.1	5.1	0.8	1.2
Soil	180	183	190	5.7	16.7	60.0	16.0	18.1	4.7	2.4	1.0
Coir	180	183	187	4.7	16.0	68.9	10.6	20.5	5.3	0.4	1.1
Bark	180	182	185	4.7	16.3	71.9	13.4	18.5	4.9	1.2	1.0
Coir mix	180	183	186	4.0	16.3	70.1	11.0	19.9	5.1	2.4	1.1
Paper	181	184	187	4.3	17.0	54.2	17.8	17.2	4.7	2.1	1.1
Sawdust	181	183	189	5.3	16.7	64.0	13.1	19.3	5.0	1.6	1.0
Rockwool	181	184	186	3.7	16.0	62.9	12.8	19.5	4.6	0.4	1.0
Straw	182	185	189	4.7	17.0	62.8	13.8	19.4	4.6	2.6	1.0
SED (df=38)	0.8	0.7	1.6	1.50	0.60	2.14	0.76	0.44	0.25	1.41	0.57
Significance											
(substrate)	***	***	***	NS	NS	***	***	***	**	NS	*
(treatment)	***	***	***	NS	NS	***	NS	***	**	NS	NS
(interaction)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

For statistical significance, see footnote to Table 3

CONCLUSIONS

The trials showed the robustness of forced narcissus when grown in a wide range of substrates. The first experiment showed that, in a limited range of more 'commercial' substrates, all aspects of performance were satisfactory, including in early-season, heat-treated crops when stresses are expected to be greater. The second experiment showed that many waste materials could be employed for narcissus forcing: even materials with very high AFP values could be used when mixed with peat. The wide applicability of waste materials indicates that a variety of locally available substrates could be exploited. Several materials were suitable substrates when used in pot-plant production, all with good responses to applied retardant. Further work on narcissus should concentrate on evaluating mixtures of cheap, open-textured materials (such as chopped straw) with denser, water-holding materials other than peat (such as coir or sawdust). These trials should be on a large scale, so that any practical management difficulties can be properly assessed. Crop quality aspects (eg stem strength and foliage colour as well as stem length and vase- life) should be considered in more detail. Sterilisation and re-use of alternative materials should also be examined.

As expected, the performance of tulips was much more dependant on the exact nature of the substrate, with poor tolerance of low pH, low AFP or high conductivites. Further work is needed on using waste materials, such as straw, as an extender for peat or coir, and on developing appropriate management for such mixes. The relationship between crop stress (eg, in relation to early and late forcing rounds) and adverse substrate properties needs to be better understood by critical experimentation.

With lilies, the preliminary trial reported here showed there were good prospects for using non-peat substrates. Coir and coir mix appeared to be ready alternatives to peat, and it is likely that mixtures of peat or coir with a variety of high-pH waste materials would be equally successful. Further work needs to be carried out to investigate how best to provide the nutritional requirements of lilies growing in waste materials such as bark, straw or paper.

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