Project title:	Column stocks (cut-flowers): An Investigation into the cause(s) of poor establishment, growth and flower uniformity in commercial crops (PO 005) To investigate the commercial scale use of various soil amendments to improve the quality and disease control in glasshouse grown crops of stocks, following on from the results of PO 005 (PO 005a)
Project number:	PO 005 and PO 005a
Project leader:	Lyndon Mason Director, L&RM Consultancy Ltd
Report:	Final Report, 2013
Previous report:	None
Key staff:	Lyndon Mason (L&RM Consultancy Ltd) Martin McPherson (Stockbridge Technology Centre (STC))
Location of project:	Various commercial nurseries in Lincolnshire and Norfolk STC
Industry Representative:	Colin Frampton
Date project commenced:	1 January 2011
Date project completed (or expected completion date):	31 December 2013

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AUTHENTICATION

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

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GROWER SUMMARY

Headline

- As a result of these findings, growers of column stocks have started to move away from sterilising with Basamid to using steam sterilisation. This particularly applies where varieties of the 'Aida' and 'Figaro' Series are grown.
- Using steam-sterilisation reduced problems with *Pythium* and poor root development, even in sub-optimal growing conditions in poor quality glasshouses.
- *Fusarium* is still potentially a major problem on some nurseries, especially on sites with a history of the disease, and this was still the case in some glasshouses even where the soil had been steamed (steaming for 6 to 8 hours does not always fully control *Fusarium*).
- The varieties 'Centum Deep Blue', 'Fedora Deep Rose' and 'Francesca' are particularly susceptible to *Fusarium*.
- Growers and propagators should work more closely together to match the choice of varieties to the growing practices used.
- The varieties 'Figaro Lavender' and 'Figaro Light Rose' have shown symptoms similar to *Rhizoctonia*, although laboratory tests identified the cause as a strain of *Fusarium* that shows up as a yellow culture on agar plates.
- Loose-fill plugs, now being used by the main propagator, give better results than the glue-plugs previously used in terms of plant establishment.
- The variety 'Carmen Yellow' was found to be particularly slow and uneven on some nurseries.

Background

Over the past few years, UK producers of column stocks have seen an increasing incidence of problems leading to plant losses and a reduction in the marketable percentage of the crop. In some cases the percentage unmarketable crop has been as high as 50%, but on average it is closer to 15%. Currently, crops are failing to establish, grow and flower uniformly, with resultant increased labour costs owing to increased grading and repeated picking. Unless resolved, this problem could result in UK growers ceasing to grow an otherwise highly acceptable cut flower crop that is in demand. Project PO 005 was an investigation into the cause or causes of poor establishment, growth and flower uniformity in commercial crops of column stocks.

Various reasons for these failings have been suggested by growers, ranging from establishment problems due to the glue plug being used through to poor seed quality.

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Surveys undertaken in 2011 and 2012 were generated to try and understand these various issues. The findings from the surveys led to nursery based trials as well as pot trials investigating the use of chemical and biological treatments with potential to control both *Pythium* and *Fusarium*, the objective being to improve the quality of UK-grown column stocks, if necessary through follow-up projects.

Summary

Surveys of grower practices (PO 005)

The 2011 and 2012 surveys were a comprehensive review of the column stock industry and included a large proportion of the UK businesses, covering about 90% of production of this crop. The main findings from the surveys are listed below:

- The total number of column stocks planted in 2011 was approximately 12 million seedlings, of which approximately 9 million were grown in steamed soil, about 2.3 million in soil sterilised with Basamid (dazomet), and about 0.8 million in non-sterilsed soil. Of the nine million grown in steamed soil, about 49% were grown in soil sterilised by dry (super-heated) steam and about 26% in soil sterilised by ’wet’ steam.
- In 2012, the corresponding production figures were about 13 million in total, comprising about 12.4 million grown in steamed soil, about 0.6 million in Basamid sterilised soil, and a negligible amount in non-sterilsed soil. Of the 12.4 million grown on steamed soil, about 59 and 36% were grown in soil sterilised by dry (super-heated) and ‘wet’ steam, respectively. The change in practice from 2011 to 2012, moving from sterilising with Basamid to steam sterilisation, was a direct result of the earlier year’s findings.
- Growers who had steam-sterilised the soil suffered from very few problems with *Pythium* or poor root development, even in poor quality glasshouses with less than ideal growing conditions.
- Growers who had not used any form of soil sterilisation, or had used Basamid, consistently had problems with certain varieties, namely from the ‘Aida’ and ‘Figaro’ Series. As some 75% of the total area in 2011 was steamed, the overall percentage of the 12 million column stocks grown affected by this problem was probably no greater than 5%. But for those growers who had not steamed and were growing ‘Aida’ and ‘Figaro' varieties this was a very serious problem and some crops showed 50 to 90% of stems affected. The problems observed in these varieties were poor root development, lack of vigour and loss of marketable stems, wilting and

sometimes plant collapse and death and in such cases *Pythium* was consistently isolated from the affected plants in 2011.

- It was agreed by the main propagator and breeder that the 'Aida' and 'Figaro' varieties are weaker rooted and would therefore be prone to problems on non-steamed soil. It was agreed that growers and propagators should work more closely together to match the choice of varieties to the growing practices used.
- Both years of the survey showed that *Fusarium* was still potentially the major problem on some nurseries, especially on sites with a history of the disease. In some situations this was the case even where the soil had been steamed, steaming for six to eight hours did not always fully control *Fusarium*.
- In 2011, *Fusarium* mainly occurred in later planted crops and in two particular varieties, 'Centum Deep Blue' and 'Francesca' which could be seriously affected. Out of the total of about 12 million column stocks grown, however, only about 5% was lost through *Fusarium*. Where susceptible varieties were grown, the losses varied widely from nursery to nursery, some experiencing negligible losses and others losses in excess of 50%. These results were confirmed in 2012, but, unexpectedly, the variety 'Fedora Deep Rose' also suffered from a moderate to severe infection on some nurseries.
- In 2012, problems were also seen in the varieties 'Figaro Lavender' and 'Figaro Light Rose' which appeared initially similar to *Rhizoctonia*. The problem occurred on scattered individual plants rather than in patches, and the symptoms showed within two weeks of planting, even as early as late-February. However, laboratory tests identified the cause as a strain of *Fusarium* which developed as a yellow culture on agar plates. The suggestion that the disease had been brought in with seedlings could not be proven. But no more than 1 or 2% of a batch was affected and, unlike the usual strain of *Fusarium* it did not spread to adjacent plants and did not occur again in the following season. Exact identification did not prove possible, but it was thought it was another strain of *F. oxysporum*.
- There was broad industry agreement that the current column stocks varieties are flowering more unevenly than they did a decade or so ago, and it is now necessary to pick them two or three times rather than as a one-off cut.
- The need to ensure good seed selection and stock maintenance to ensure a more even crop has been taken on board by growers, propagators and breeders.
- The main propagator's decision to move from glue plugs to loose-fill plugs was a positive move and initial plant establishment has been better, but the loose-fill plug needs to be made more stable to facilitate better gapping-up and planting. As a

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result the main propagator has installed a new filling machine and conducted a number of trials with the new plug.

- In addition some growers experienced poor establishment and slow growth of the variety ‘Carmen Yellow’. Most of the crop was eventually marketable but it was uneven and 10 to 14 days behind other varieties in the same glasshouse. This occurred only in a small number of plantings on three nurseries.

Pythium glasshouse trial (PO 005)

A *Pythium* trial was undertaken in two glasshouses on a commercial nursery, one glasshouse contained non-sterilised soil that had a history of *Pythium*-like symptoms and in an adjacent glasshouse the soil had been sterilised by steam. 15 biopesticides and other treatments were tested on the varieties ‘Aida White’ and ‘Figaro Lavender’. The treatments included Trianum (*Trichoderma* species) both drenches to the soil and application at propagation, applications of HDC F45, Prestop, Serenade ASO (all biopesticides) and Paraat and Subdue (both conventional fungicides), as well as Trianum and Prestop drenches combined with the incorporation of paper waste or spent mushroom compost into the soil. The addition of products with specific activity against *Pythium* did not reduce the poor rooting associated with these two plant varieties. The only improvement came from the addition of spent mushroom compost.

Fusarium glasshouse trial (PO 005)

This trial was also undertaken on a commercial nursery, in a glasshouse with a history of *Fusarium* related problems. Half of the soil in the glasshouse had been steam-sterilised before producing an early round of column stocks, after which the trial was planted without further sterilisation. The other half of the soil in the glasshouse was steamed before planting the second round. Each area was planted with the varieties ‘Centum Deep Blue’ and ‘Francesca’ because of their sensitivity to *Fusarium*. The treatments included Trianum and HDC F45 (soil drenches and application at propagation) and HDC T34 as a plug-tray soak, applications of Prestop and Serenade ASO (biopesticides) and Octave, Signum and Switch (conventional fungicides), as well as Trianum and Prestop drenches combined with the incorporation of paper waste, spent mushroom compost or composted bark, and mushroom compost or composted bark used on their own. None of the fungicides or biopesticides showed any control of *Fusarium*. However, the incorporation of composted bark showed a significant level of control of *Fusarium* and an overall improvement in the quality of the stems not affected with *Fusarium*.

Pythium and *Fusarium* pot trials (PO 005)

Pot-plant trials were carried out at Stockbridge Technology Centre, Cawood, North Yorkshire. The pathogens used to inoculate the test plants were virulent strains isolated from confirmed infected column stocks samples. Two varieties of columns stocks were used because of their observed susceptibility, 'Figaro' for the *Pythium* studies and 'Francesca' for *Fusarium*. The range of treatments used was similar to that tested in the glasshouse trials though with additional experimental products. Two drench applications were made, immediately post-sowing and then 21 days later.

In the *Pythium* pot trial, none of the applied treatments were found to be effective at controlling *Pythium* when compared with the inoculated control. There were however, several treatments that appeared to increase the levels of post-emergence damping-off, the most notable being Serenade ASO and the experimental products HDC F132 and HDC F128. Differences in plot vigour were observed, with PlantTrust producing a significant increase in vigour compared with all other treatments, though this may have been due to the presence of additional nutrients in the formulation.

In the *Fusarium* pot trial, all of the varied treatments reduced the number of seedlings emerging (although treatment at this time with many of the products examined would not be standard practice). Following inoculation by *F. oxysporum* f.sp. *matthioli,* vascular wilt developed rapidly and 90% of the seedlings died in the inoculated control. The non-inoculated control remained disease-free throughout the study. Only two of the applied treatments, Systhane and Octave, resulted in a significant decrease in *Fusarium* infection levels, by 32 and 85% respectively, compared with the inoculated control, and none of the other treatments had any significant effect (although due to an application error the rate of Octave applied was much higher than the label recommendation, so this result needs interpreting with caution). No significant differences in plot vigour were observed between treatments, nor were any phytotoxic effects seen during the trial, although four weeks after the cessation of the trial there was some severe leaf curling and distortion in several of the Octave-treated plots.

Bark incorporation glasshouse trials (PO 005a)

In 2013 there was further testing of the promising bark incorporation trials against *Fusarium*. This was undertaken on a large-scale at a number of commercial nurseries, and included a range of bark application rates including full-rate (30 L/m^2), half-rate, first- and second-round incorporation, pre- and post-steaming incorporation as well as interactions with Basamid sterilisation and composted green material incorporation. None of the treatments or sites showed any advantage due to the incorporation of composted bark.

Financial Benefits

At an average planting density of 64 plants/m^2 every square metre of lost crop represents about £16 of lost income in terms of revenue from the cut flowers. Hence if the industry was losing between 5 and 10% due to unidentified problems, on a total area of about 30 ha (300,000 m^2) this would represent between £240,000 and £480,000 per annum. The first year of this survey identified a number of key action points for growers which will help to reduce crop losses.

Financial losses also occur as a result of the down-grading of lower quality stems and repeat harvesting of uneven crops. The use of appropriate varieties to suit time of year and sterilisation method will help reduce these financial losses.

At the 2014 review of the Cut Flower Centre there was broad agreement amongst the largest column stock growers that the bringing together of the industry, including the crop walks, was one of the major achievements of this project but that it was very difficult to put a value on it. However, the general feeling of the growers was that in its totality, this project had increased the overall number of stems marketed by between 2 and 5%, which on a total of 15 million at 25p per stem (2014 figures) would equate to an extra annual income of between £75,000 and £187,500.

Action Points

The following action points should be considered as a result of the both the survey and trials carried out from 2011 to 2113.

- Investigate any unexplained plant losses or areas of poor growth and consider sending samples for laboratory analysis of the problem.
- If growing on soil that has not been steamed, avoid planting varieties from the 'Aida' and 'Figaro' Series.
- If the glasshouse soil has a history of *Fusarium*, try to avoid late plantings of 'Centum Deep Blue', 'Francesca', and 'Opera Deborah'.
- Work closely with plant suppliers to ensure the correct varietal choice.
- Ensure that any soil to be steamed has been cultivated to ensure it is not too wet and has a good structure to allow the steam to penetrate to depth.
- The trials indicate there is limited scope to control either *Pythium* or *Fusarium* infestations in the soil using the current range of conventional fungicides and biopesticides applied at the label recommended rates.
- Growers should liaise with their local suppliers to keep updated with progress and possible future beneficial treatments.

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SCIENCE SECTION

Introduction

With sturdy flowers, a good range of colours, ‘guaranteed’ fragrance and a long cropping season, stocks are popular cut-flowers routinely carried by most of the major retailers, who have a preference for the superior, UK-grown product. Over the past few years UK producers of column stocks have seen an increasing incidence of problems leading to plant losses and a reduction in the percentage of the crop that is marketable. In some cases this loss was up to 50%, but an average would probably be nearer to 15%. In reality a minimum of 90% of the plugs are required to reach a marketable stage and achieve profitability on most nurseries. Unfortunately, crops are currently failing to establish, grow and flower uniformly, with resultant increased labour costs through increased grading and repeated picking. Unless resolved, this could result in UK growers ceasing to grow an otherwise highly acceptable cut-flower crop that is in demand.

Several reasons for these problems have been suggested by growers, ranging from establishment problems arising from the glue plug, through to poor seed selection. However there was no agreement among the industry of the cause, leading to a loss of confidence in the product and a subsequent reduction of about 10% in the overall production area at a time when the supermarket demand has never been higher. This was the reason for the HDC instigating a detailed survey of industry practices in 2011.

At that time there were three main propagators supplying plug-raised column stocks into the UK, Florensis Cut Flowers, van Klink and Combinations (van Klink has subsequently been taken-over by Florensis). The propagator with the largest market share is Florensis, who work closely with Pan American Seeds, the breeder supplying most of their seed. Hence, Florensis offer an exclusive range of varieties such as Aida, Fedora, Figaro, Carmen and Opera, as well as those offered by other propagators, such as Centum and Anytime. Van Klink also offered their own range - Phantom and Fantasy - while Combinations offers Jordyn. However, there is strong circumstantial evidence from variety trials and commercial observations, and from discussions with Pan American Seeds, that many of these varieties have been selected from the Pan American range and renamed by the propagators, a perfectly legal practice since the seed is not protected by Plant Variety Rights.

This project involved a two-stage approach, with the first year (2011) dedicated to a fact-finding survey mainly involving four key growers collectively representing about 60% of the UK column stock industry. The survey involved weekly visits by the Project Manager to assess the extent of the problem in each growing unit and record key agronomic factors such as variety, seed supplier, soil type, chemicals applied, temperature, method of sterilisation, time from sterilisation to planting, etc. Appropriate analyses were also undertaken for soil nutrient status, presence of disease, etc.

For year two (2012), the findings from year 1 were used to identify key issues and then undertake appropriate trials on grower's holdings and at Stockbridge Technology Centre (STC). These centred on *Pythium* and *Fusarium* control, with the trials on grower's holdings heavily focused on biological solutions and those at STC concentrating on chemical solutions. The survey was continued (with a reduced frequency of visits) to confirm the findings of the trials and monitor the solutions being implemented by growers, such as the selection of varieties to suit the sterilisation technique used.

The ultimate aim of the project was to elucidate the cause(s) of the recent, but persistent, plant failure and variable crop uniformity, and to propose solutions to ensure the continued viability of UK stock production.

Materials and methods

2011 survey

The 2011 survey involved a large proportion of the column stock industry, with about 90% of the total production area involved in one form or another. Four key growers, who collectively produced about 7 million stems and represent 60% of total English production, participated in the detailed survey. In addition, the Project Manager visited seven growers who collectively produced another 4 million stems.

Collectively these growers were using 68 glasshouses, giving a very broad survey in terms of size and type of house, soil type and growing technique. A total of 82 visits were made between 11 March 2011 (week 10) and 21 July 2011 (week 29). Details of the four main growers are given below.

Grower 1 operated out of multiple sites and the survey was undertaken in 20 glasshouses with planting dates from week 7 to week 22, five of the glasshouses producing a second round. The glass ranged from modern, multi-span Venlo houses, through old, wide-span houses, to old, low Dutch-light houses and Spanish tunnels. All soil was steam-sterilised close to planting before each round, including the second round.

Grower 2 also operated out of multiple sites, with the survey undertaken in four glasshouses, mainly modern Venlo houses. Planting dates ranged from week 9 to week 16 and no second-round plantings were made. Soil was sterilised with Basamid in autumn 2010 and steam in autumn 2011.

Grower 3 operated out of one site, with the survey undertaken in eleven glasshouses with planting dates from week 7 to week 24, with six glasshouses producing a second round. All were modern Venlo houses of varying age. Apart from two, the houses were steam-sterilised in autumn.

Grower 4 also operated out of one site with the survey undertaken in three glasshouses with planting from week 7 to week 25, two of the glasshouses producing a second round. The houses were sterilised with Basamid in winter 2010/11 and with steam in autumn 2011.

These four growers, who also made-up the project steering group, were visited every 7 to 10 days throughout the production period. During visits each of the glasshouses was walked in detail and the progress of crops noted by variety. Where a disease problem was observed samples were sent to STC Plant Clinic for analysis (except for later problems with *Fusarium* which did not need formal identification). The growers also participated in crop walks of each other's nurseries throughout the growing season.

As well as the four main growers, other stock growers were visited when the Project Manager was made aware of a problem, and towards the end of the season most of the remaining growers, who had not been involved until then, were also visited. During these visits a note was made of any problems, the varieties grown and sterilisation technique used. If necessary, samples of diseased plants were sent to the STC Plant Clinic for diagnosis. Table 1 shows the varieties and methods of soil sterilisation used in 2011.

Table 1. Column stock varieties and soil-sterilisation methods from the 2011 survey

Variety	Steam	Basamid	None	Variety	Steam	Basamid	None
Aida Blue	✓	✓		Fantasy Rose		✓	
Aida Lavender			✓	Fedora Deep Rose	✓	✓	
Aida White	✓	✓	✓	Figaro Lavender	✓	✓	✓
Anytime Lavender			✓	Figaro Rose Light	✓	✓	✓
Anytime Rose			✓	Jordyn Cream	✓		
Anytime Sea Blue			✓	Jordyn Deep Blue	✓		
Anytime White			✓	Jordyn Lavender	✓		
Anytime Yellow			✓	Jordyn Light Rose	✓		
Carmen Yellow	✓	✓	✓	Jordyn Red	✓		
Centum Deep Blue	✓	✓		Jordyn White	✓		
Centum Red	✓	✓		Opera Deborah	✓	✓	
Centum White	✓	✓	✓	Opera Francesca	✓	✓	✓
Centum Yellow	✓			Phantom Dark Rose		✓	
Fantasy Cream Imp		✓		Phantom Early White		✓	
Fantasy Deep Blue		✓		Phantom Milka		✓	
Fantasy Lavender		✓		Phantom Red		✓	
Fantasy Red Imp		✓		Phantom Rose		✓	

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In addition to the survey, an informative visit was arranged with Florensis and Pan American Seed to visit Dutch stock growers and propagation facilities and to look at breeding and seed selection (31 May to 1 June 2011). Finally, a trip was arranged in August 2011 to visit stock growers in Northern Ireland and to look at trials at Greenmount College (2 and 3 August 2011).

2012 survey

As in 2011, the 2012 survey involved, in one form or another, a large proportion of the column stock industry, about 90% of the total production area. The same key growers as in 2011 were involved in the detailed survey, and in 2012 they collectively planted about 8.8 million plugs, representing about 70% of the total English production. In addition the Project Manager also visited a further six growers who collectively produced another 3 million stems. Collectively these growers were producing in 63 different glasshouses again giving a very broad survey sample. Visits were made between 30 January 2012 (week 5) and 30 August 2012 (week 35), with a total of 61 visits. Table 2 shows the varieties and methods of soil sterilisation used in 2012.

Table 2. Column stock varieties and soil-sterilisation methods from the 2012 survey

Variety	Steam	Basamid	None	Variety	Steam	Basamid	None
Aida Blue	✓			Fantasy Rose	✓		
Aida Lavender				Fedora Deep Rose	✓	✓	
Aida White	✓	✓ (trial)		Figaro Lavender	✓	✓ (trial)	
Anytime Lavender	✓			Figaro Rose Light	✓		
Anytime Pink	✓			Jordyn Cream	✓		
Anytime Rose	✓			Jordyn Deep Blue	✓		
Anytime White	✓			Jordyn Lavender	✓		
Anytime Yellow	✓			Jordyn Light Rose	✓		
Carmen Yellow	✓	✓		Jordyn Red	✓		
Centum Deep Blue	✓			Jordyn White	✓		
Centum Red	✓			Opera Deborah	✓	✓	
Centum White	✓	✓		Opera Francesca	✓	✓	
Centum Yellow	✓			Phantom Dark Rose	✓		
Fantasy Cream Imp	✓			Phantom Early White	✓		
Fantasy Deep Blue	✓			Phantom Milka	✓		
Fantasy Lavender	✓			Phantom Red	✓		

In addition a visit was also made on 19 June 2012 to look at the production of the column stock seeds used by Florensis.

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The 2011 and 2012 data ensured that the survey was truly representative of the industry, actually representing about 90% of the English column stock production in both years. Tables 1 and 2 show there had been a move away from growing problem varieties, such as Aida and Figaro, in anything other than steamed soil. No commercial crops were observed in 2012 that had been grown in unsterilized soil, except for one small glasshouse which was used for the *Pythium* trial and was then followed by the grower's own variety trial. A variety trial at the National Cut-flower Trials Centre (CFC) was also planted into non-sterilised soil, and these results can be found in the 2012 final report for project PO BOF 002.

Pythium **glasshouse trial**

The *Pythium* trial was undertaken at a grower's holding in a non-sterilised glasshouse that had a history of *Pythium*-like symptoms and in an adjacent glasshouse that had been sterilised by steam. The non-sterilised trial was fully replicated with 15 biological and other treatments (Table 3) and four replicates. The trial in the steamed area consisted of a single replicate of all 15 treatments. Each plot was planted with equal numbers of Aida White and Figaro Lavender plugs, since the 2011 survey had shown these to be weak-rooted varieties prone to *Pythium* when grown in non-sterilised soil. Irrigation water was sterilised using a UV system, and tests in 2012 showed that it was killing all pathogens present in the water from the reservoir.

Table 3. Details of treatments used in the 2012 *Pythium* trial

No.	Product	Active ingredient	Rate
1	-	Control	-
2	-	Control	-
3	Trianum at propagation	Trichoderma harzianum	-
4	Trianum drench + propagation	Trichoderma harzianum	0.6g/m^2
5	Trianum drench + propagation	Trichoderma harzianum	1.2g/m^2
6	Trianum drench	Trichoderma harzianum	1.2g/m^2
7	HDC F45	Trichoderma sp	0.6g/m^2
8	Subdue	Metalaxyl-M (standard)	0.0625ml/m^2
9	Paraat	Dimethomorph	0.3g/m^2
10	Prestop	Gliocladium catenulatum	5g/m^2
11	Serenade	Bacillus subtilis	1ml/m^2
12	Trianum drench + lignum (paper waste)	Trichoderma harzianum	1.2g/m^2
13	Trianum drench + chitin (mushroom compost)	Trichoderma harzianum	1.2g/m^2
14	Prestop drench + lignum (paper waste)	Gliocladium catenulatum	5g/m^2
15	Prestop drench + chitin (mushroom compost)	Gliocladium catenulatum	5g/m^2

The glasshouse soil was rotavated with a Kubota machine to about 15cm deep (16 March 2012). Plots 2.9m-long were marked-out on beds 1m-wide with 0.5m-wide paths, there being six beds in the non-steamed area and 1½ beds in the adjacent steamed area.

The fresh mushroom compost was a standard commercial grade bought in from Holland as slabs and delivered fresh to the trial site. Paper waste was a by-product of the paper recycling process at the Palm Paper factory, Kings Lynn, Norfolk. Fresh mushroom compost and paper waste were applied to the appropriate plots (treatments 13 and 15, and 12 and 14, respectively) at 50kg product per plot, equivalent to about 17kg/m^2. (19 March 2012). All bed markings were then removed (except for steel stakes at the end of each bed) so that the whole area could be rotavated with a slow walk-behind rotavator so that any spread of additives into adjacent beds was minimised. Soil samples were taken immediately after rotavating from the two plots in the steamed house that had either paper waste or mushroom compost applied (plot 65 and 71) to examine their effects on pH and nutrient levels. Fertiliser was applied as 50g/m^2 triple-superphosphate and 150g/m^2 sulphate of potash) and the glasshouse rotavated and wires put down ready for planting (23 March 2012). Plots were re-marked and labelled using the original metal stakes at the end of each bed as markers to ensure positions were accurately maintained.(24 March 2012). Using a watering can, two trays each of Aida White and Figaro Lavender were drenched at a rate of either 9.4ml Subdue per 100L of water or 1g Paraat per 1L of water of Paraat (treatments 8 and 9 respectively) (24 March 2012).

On 26 March 2012 the trial was planted between 07:00 and 16:00h. To reduce the risk of errors, firstly all the plugs treated with Trianum at the propagation stage were planted, then the Subdue-treated plugs, then the Paraat-treated plugs, and finally the remaining plugs, starting at bed 1 and moving over to bed 6. The non-steamed trial was planted first, after which the boots, tools, etc. were sterilised before planting the steamed area. A plan of the trial is shown in Figure 1. At planting the weather was very warm and sunny and the crop was watered for 2 minutes using plain water from overhead lines once all plots had been planted. The rate of water output was 0.4L/m^2/min. Samples were taken from the Aida White and Figaro Lavender plugs which had been treated with Trianum at the propagation nursery and then sent to Koppert for testing for the presence of *Trichoderma*.

On 27 March 2013 the drench treatments were applied using an ‘Oxford’ precision sprayer. Because of the hot, sunny conditions the crop was irrigated for 2 minutes to reduce plant stress and they were lightly watered by hand to wet the surface prior to the application of the chemical treatments. The drenches were applied between 12:15 and 16:30h. The plots were then watered for 10 minutes which applied approximately 4L of water/m^2. Soil samples were taken from the plots treated with paper waste and mushroom compost plots in the

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steamed bed to compare with the baseline prior to treating with the products. On 16 April 2012 a second drench of Paraat was applied to the relevant plots (using the rates and methods above) and irrigated for 2 minutes. Thereafter the crop was grown by the grower using the same protocol as for his commercial crop.

The crop was ready for harvesting in early-June. On 5 June 2012, as they were a few days ahead of those in the non-steamed area, the plots in the steamed area were assessed using the following protocol. Each 0.5m at the end of the plots was treated as a guard area and ignored for sampling purposes, as were the outside double-planted rows. Therefore the actual sample consisted of ten plants (shown as X below) from the inner three rows of each variety in a fixed sampling sequence:

			X					X					X		
		X			X		X			X		X			
						X					X				
Outside double-row															

If any plant in the square was obviously not representative of the norm it was ignored and an adjacent plant sampled instead. For each sampled stem the total length was measured (from the top of the soil to the tip of the flowering spike) and then the stem was cut to a specified length (52cm) and weighed. A random stem of each variety from each plot was also dug up and the roots washed to see if there was any noticeable difference in root structure. Photographic records were taken of the overall stem and the root structure in close-up of both varieties. Root samples were taken of one plant for each colour, replicate and treatment of all of the Trianum-treated plots, along with a control (ten roots per treatment). These were promptly posted in a cool (polystyrene) box with cool packs to Koppert for assessment of *Trichoderma*.

On 10 June 2012 all plots in the non-steamed area were harvested and assessed as described above, all assessments being done between 10:30 and 18:00h. It was a warm day and the plants were showing signs of wilting as previously observed on these varieties growing in non-steamed soil during the 2011 and 2012 trial. In order to determine the level of wilting a visual assessment was undertaken at midday using a 0 to 5 score where 0 is no wilting and no soil visible through the crop canopy, up to 5, which was severe wilting with a lot of soil visible. Final soil samples were taken from plot 65 and 71 of the steamed area. A root sample of badly wilted stems of each variety was send to STC for testing for disease. The remaining unmarketable stems in the steamed plots were counted and the area cleared to enable the grower to cultivate and replant. Finally the number of waste stems was counted.

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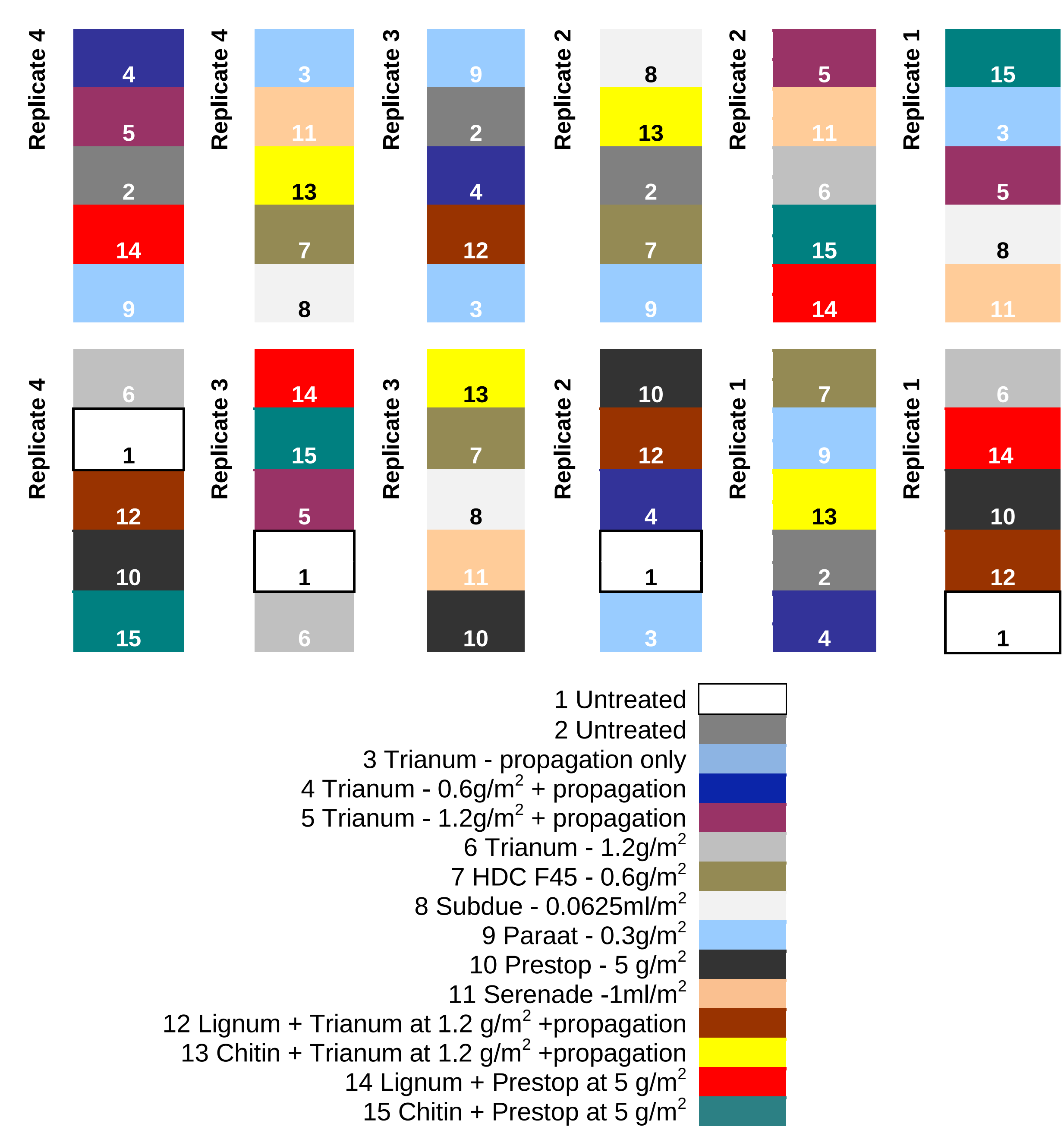

Figure 1. Plot layout and treatment key for the *Pythium* trial in non-sterilised soil

Fusarium glasshouse trial

The trial was undertaken on a grower's holding in a glasshouse with a history of *Fusarium* problems. The house had been steamed in February 2012 before producing an early round of column stocks, after which the trial was planted as a second round without any further sterilisation. The other half of the glasshouse was steamed before planting the second round of column stocks and part of this area was also used for the trial. The non-sterilised trial consisted of a fully replicated layout with 24 treatments and four replicates. The trial in the steamed area consisted of a single replicate of all 24 treatments. Each plot was planted with equal numbers of Francesca and Centum Deep Blue plugs because previous observations showed these varieties to be very prone to *Fusarium*. The biological and other treatments are shown in Table 4.

Table 4. Treatments used in the 2012 *Fusarium* trial

No.	Product	Active ingredient	Rate
1	Control	-	-
2	Control	-	-
3	Control	-	-
4	Trianum at propagation	Trichoderma harzianum	-
5	Trianum drench + propagation	Trichoderma harzianum	0.6g/m^2
6	Trianum drench + propagation	Trichoderma harzianum	1.2g/m^2
7	Trianum drench	Trichoderma harzianum	1.2g/m^2
8	HDC F45 at propagation	Trichoderma sp.	-
9	HDC F45 drench + propagation	Trichoderma sp.	0.4g/m^2
10	HDC F45 drench	Trichoderma sp.	0.6g/m^2
11	Octave	Prochloraz-Mn	2g/L
12	Signum	Pyraclostrobin + boscalid	1.35kg/ha
13	Switch	Cyprodinil + fludioxonil	0.8kg/ha
14	Prestop	Gliocladium catenulatum	5g/m^2
15	Serenade	Bacillus subtilis	1ml/m^2
16	Trianum drench + lignum (paper waste)	Trichoderma harzianum	1.2g/m^2
17	Prestop drench + lignum (paper waste)	Gliocladium catenulatum	5g/m^2
18	Trianum drench + chitin (mushroom compost)	Trichoderma harzianum	1.2g/m^2
19	Prestop drench + chitin (mushroom compost)	Gliocladium catenulatum	5g/m^2
20	Trianum drench + composted bark	Trichoderma harzianum	1g/m^2
21	Prestop drench + composted bark	Gliocladium catenulatum	5g/m^2
22	T34 soak of plug trays	Trichoderma asperellum	0.01g/L
23	Mushroom compost	-	-
24	Composted bark	-	-

On 26 May 2012 the trial area was rotavated and power-harrowed by tractor. The previous day there had been a burst water main at the path end of replicate 2, water-logging plots 17, 18, 25 and 26. As a remedial measure the grower applied drier soil on the waterlogged area on 28 May and this dried out well due to hot weather. After cultivation all plots were marked out with string and canes. Baseline soil samples were taken from one plot of paper waste, mushroom compost and bark from both steamed and non-steamed areas, before applying the relevant soil incorporant (plot numbers 12, 37, 63, 98, 107 and 114). Paper waste was applied to the relevant plots at 17kg/m^2. On 28 May fresh mushroom compost was applied to the relevant plots at 17kg/m^2, and composted bark was also applied to the relevant plots at a rate of 85L/plot, about 30L/m^2 (the recommendation from Melcourt was 32L/m^2 but not quite enough bark was available to use this rate). Ammonium nitrate was applied to each of

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the bark plots at 85g/plot, also as per Melcourt's recommendation. The additives on each plot were levelled out and the strings and canes removed ready for rotavating.

On 29 May the beds were rotavated with a Kubota powered rotavator to about 10 to 14cm deep. At the end of each soil treatment the rotavator was lifted and moved slightly forward to avoid spread from one plot to another. The plots were then re-marked and further soil samples taken from the six beds previously sampled before soil incorporation. Two trays of Francesca and Centum Deep Blue were soaked in T34 in trays that held about 10L solution made up at a rate of 1g/100L, trays being left to soak overnight.

The trial was planted on 30 May 2012. As with the *Pythium* trial the trays treated at the propagation stage were planted first to reduce errors. The split plots were made up of Francesca on the left-hand side and Centum Deep Blue on the right (looking from the central pathway). Then the other plots were planted. Once planted the area was watered with 15 minutes of overhead irrigation. A plan of the trial is shown in Figure 2. The chemical treatments were applied to each plot on 31 May 2012, following which all plots were watered for 15 minutes using the overhead irrigation (equivalent to 5L of water/m^2) to wash in the chemicals. Samples were taken of plugs from trays for Koppert to test for *Trichoderma*. Between 1 and 14 June 2012 several plants in the mushroom compost plots were observed to be dying-off. On 15 June 2013 downy mildew was observed and so Fubol was applied along with Toppel for flea beetle.

Plots were assessed on 27 July in the steamed area and on 28 July in the non-steamed area:

- Stem length was measured for ten stems per plot, the stems being selected as shown by 'X' on the following grid:

				X	X			X				X				X							
						X				X				X				X	X				

- The degree of *Fusarium* infection of the same ten plants per plot were assessed on a scale of 0 to 5 according to the following scores:

Score	Description
0	Plant died for a reason other than *Fusarium* (mainly mushroom compost)
1	Very severe *Fusarium* – no or little green tissue left
2	Severe *Fusarium* but tissue still mainly green
3	Stem has flowered but has obvious *Fusarium*
4	Stem has little obvious *Fusarium* but is less than 45cm long
5	Marketable stem

- The total number of marketable stems per plot was recorded, a marketable stem being defined as one with a minimum total length of 45cm, a minimum spike length of 12cm and no obvious signs of pest and disease
- Ten random marketable stems per plot were cut to a length of 45cm and weighed.

The following assessments were made on 31 July

- For plots not yet flowering (mainly in mushroom compost and paper waste treatments) the *Fusarium* score (see above)
- For the same plots an estimate of the amount of marketable stems was made
- Samples were taken of all Trianum plots in steamed and non-steamed areas, and of the control plus mushroom compost and bark plots without Trianum (in the non-steamed area it was difficult to find enough green plants in some treatments and the roots were very poor)
- Final soil samples were taken from the same plots as previously (all samples were placed in a cold store overnight)
- The ten samples from the steamed plots, now marketable, were taken.

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19	2	13
16	3	24
20	12	5
18	7	6
23	8	22
15	14	10
17	1	21
4	9	11

Replicate 4
(3 beds)

18	21	22
24	23	2
9	1	14
11	8	5
15	7	6
16	12	17
20	13	4
19	10	3

Replicate 3
(3 beds)

1	6	21
4	2	9
13	22	23
10	17	11
3	18	14
12	16	24
19	20	5
7	8	15

Replicate 2
(3 beds)

23	7	24
3	12	9
19	6	13
16	15	18
21	20	5
11	2	22
10	8	4
17	1	14

Replicate 1
(3 beds)

1	Untreated	13	Switch - 0.8kg/ha
2	Untreated	14	Prestop - 100g/20L
3	Untreated	15	Serenade - 10L/ha
4	Trianum propagation only	16	Lignum + Trianum - 12kg/ha
5	Trianum - 6kg/ha (+ propagation)	17	Lignum + Prestop - 100g/20L
6	Trianum - 12kg/ha (+ propagation)	18	Chitin + Trianum - 12kg/ha
7	Trianum - 12kg/ha	19	Chitin + Prestop- 100g/20L
8	Exp. *Trichoderma* propagation only	20	Bark + Trianum - 12kg/ha
9	Exp. *Trichoderma* - 4kg/ha (+ propagation)	21	Bark + Prestop 100g/20L
10	Exp. *Trichoderma* - 6kg/ha	22	T34 plug soak - 0.01g/L
11	Octave - 2g/l	23	Mushroom compost
12	Signum - 1.35kg/ha	24	Bark

Figure 2. Plot layout and treatment key for the *Fusarium* trial in non-sterilised soil

Pythium and *Fusarium* pot trials

The pathogens used in this study were isolated from infected column stocks samples sent to the STC Plant Clinic by the Project Manager during the first phase of study in 2011-2012. Isolates were stored on agar slopes, and pathogenicity tests were carried out to evaluate their virulence. The isolates exhibiting the highest level of virulence were selected and bulked-up for large-scale, replicated pot studies. Two cultivars of column stock seeds

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were chosen due to their observed susceptibility to the pathogens being investigated, namely Figaro for the *Pythium* studies and Francesca for *Fusarium*.

A randomized split-plot design was used to take account of three pathogen introductions (a *Fusarium* sp. and two *Pythium* spp.), with four replicate plots for each treatment and pathogen. Each plot comprised a single 2L-pot containing a minimum of 80 column stock seeds for the *Pythium* trials and 100 for the *Fusarium* trial (more Francesca seeds were available). Each pot was stood in a saucer to prevent cross contamination and to help maintain the soil at field capacity (Figure 3).

Based on prior knowledge a range of fungicide and biocontrol treatments was drawn up for each pathogen trial. Sixteen treatments were selected for the *Fusarium* study and 15 for each of the *Pythium* studies. For each treatment, two drench applications were made, the first immediately post-sowing and the second 21 days later. The treatments for each pathogen are shown in Tables 5 and 6.

Table 5. *Fusarium* treatments in the STC pot trial. All products were applied as a drench using 250ml water per pot, applying 250ml plain water to the un-inoculated controls

No.	Product	Active ingredient	Rate
1	Control	Un-inoculated control	-
2	Control	Inoculated control	-
3	Amistar	Azoxystrobin	1L/ha
4	Signum	Pyraclostrobin + boscalid	1.35kg/ha
5	Switch	Cyprodinil + fludioxonil	0.8kg/ha
6	Systhane	Myclobutanil	225ml/750L water
7	Octave	Prochloraz-Mn	2g/L
8	HDC F126	Experimental	1L/ha
9	HDC F127	Experimental	0.5L/ha
10	HDC F129	Experimental SDHI	0.4L/ha
11	HDC F130	Experimental SDHI	1L/ha
12	HDC F131	Experimental SDHI	1L/ha
13	T34	Trichoderma asperellum	10g/L
14	Serenade	Bacillus subtilis	$1ml/m^2$
15	Prestop	Gliocladium catenulatum	$5g/m^2$
16	Trianum	Trichoderma harzianum	12kg/ha

Table 6. *Pythium* treatments in the STC pot trial. All products, with the exception of treatment.10, were applied as a drench using 250ml water per pot, applying 250ml plain water to the un-inoculated controls. Treatment.10 was incorporated into substrate pre-sowing.

No.	Product	Active ingredient	Rate
1	Control	Un-inoculated control	-
2	Control	Inoculated control	-
3	Subdue	Metalaxyl-M (standard)	0.0625ml/m^2
4	Previcur Energy	Fosetyl-Al + propamocarb-HCL	3ml/m^2
5	Fenomenal	Fenamidone + fosetyl-Al	150g/100L water
6	Paraat	Dimethomorph	0.3g/m^2
7	Revus	Mandipropamid	0.6L/ha
8	HDC F128	Experimental	0.8L/ha
9	HDC F132	Experimental	0.2L/ha
10	Plant Trust	Fosetyl-aluminium	2.4Kg/m^2
11	Amistar	Azoxystrobin	1.0L/ha
12	Signum	Pyraclostrobin + boscalid	1.35L/ha
13	Serenade	Bacillus subtilis	1ml/m^2
14	Prestop	Gliocladium catenulatum	5g/m^2
15	Trianum	Trichoderma harzianum	12kg/ha

To bulk-up the pathogens needed as inocula, one isolate of *Fusarium oxysporum* and two isolates of *Pythium* spp. were recovered from symptomatic column stock plants. The isolates were cultured on Potato Dextrose Agar (PDA) amended with lactic acid (PDA-LA) to aid in minimising bacterial contaminants, and incubated at 23°C for 10 days to ensure that the isolates filled the plates. Using data from previous pathogenicity testing, the optimum pathogen inoculation level for incorporation into the substrate was one agar plate for 2L of top-soil. The agar plates were macerated and mixed thoroughly with the top-soil substrate before being added to 2L of substrate per pot. Column stock seeds were then sown on top, ensuring there was a good distribution across each pot. One to 2cm of un-inoculated top-soil was then added to the top of the pots to cover the seeds. The first drench treatment application was made and the pots left to germinate in the dark at a temperature of 14°C for 3 days. After 3 days they were moved into a cool glasshouse (15-16°C) for a further 5 days in preparation for the 'double' seedling selection phase.

When growing column stock plants from seed, a selection process is required to pick out the double-flowered plants from single-flowered plants (single-flowered plants are not marketable because of their poor flowering qualities, and are discarded at the seedling stage). This process is usually undertaken by commercial propagators using a semi-automatic process, though for small-scale trials it was done manually. The selection process involved placing the newly germinated column stocks at 3°C for 3 days and then moving tem back into a cool glasshouse (15-16°C), the cooling process causing the more

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vigorous singles to darken in colour, enabling their removal and leaving the slightly weaker, paler green double seedlings. Within 3 days of transfer to the glasshouse this colour change had become apparent and the darker singles were removed (Figure 4).

Figure 3. Layout of column stock trials prior to double seedling selection

Figure 4. The difference in colour between singles and doubles after cooling at 3°C for 3 days

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Assessments of the number of emerged plants were made at 50% emergence (6 days post-sowing) and at 100% emergence (14 days post-sowing, immediately before selection took place). Any ‘damping-off’ observed during these assessments was also recorded. After selection weekly assessments were conducted, counting the number of healthy plants remaining in each plot. Any dead plants or those showing symptoms were removed at the end of each weekly assessment. Random selections of these seedlings were taken and isolations from their vascular tissues (*Fusarium*) and roots (*Pythium*) were carried out, as confirmation of the presence of the original pathogens. The weekly assessment of the number of healthy plants was carried out for 8 weeks. Plant vigour assessments were carried out at the end of the trial. Plants were scored using a 0-100 scale as a percentage. The most vigorous plants were used to calibrate the top of the scale and were scored as 100%.

Results

Surveys

The main observations from the survey are as follows (see also Tables 7 and 8).

- The total number of column stocks seedlings planted in 2011 was approximately 12.0 million, with about 2.0 million (17% of the total) being second-round production. Of the total, approximately 75% (9.0 million) were grown in steamed soil, 19% (2.3 million) in Basamid-sterilised soil, and 7% (0.8 million) in non-sterilsed soil. Of the 9.0 million grown in steamed soil, about 5.8 million (about 49% of the total 12.0 million) were grown in soil sterilised by ‘dry’ (super-heated) steam and 3.1 million (about 26%) grown in soil sterilised by ‘wet’ steam.
- The total number of column stocks seedlings planted in 2012 was approximately 13.0 million, with about 2.9 million (23% of the total) being second-round production. Of the total, approximately 95% (12.4 million) were grown in steamed soil, 5% (0.6 million) in Basamid-sterilised soil and a negligible amount in non-sterilsed soil. Of the 12.4 million grown in steamed soil, about 7.6 million (about 59% of the total 13.0 million) were grown in soil sterilised by dry steam and 4.7 million (about 36%) in soil sterilised by wet steam.
- The surveys showed conclusively that there is no single problem affecting all column stock crops, rather a combination of factors is responsible for the problems experienced in recent years (see Tables 7 and 8).
- Growers who had steam-sterilised the soil prior to planting their crop suffered very few problems with *Pythium* or poor root development, even in poor quality glasshouses with less than ideal growing conditions, except where there had been a

specific soil structure issue, such as flooding due to a burst pipe (but even in this case it was poor root development, rather than disease, that was the key issue).

- There was circumstantial evidence from growers' observations on some nurseries that the previous year's problems had still occurred if steaming had taken place a long time before the crop was planted (e.g. autumn steaming following by spring planting). But this was not supported by observations made during either the 2011 or 2012 survey.
- Growers who had not used any form of sterilisation, or who had used Basamid, consistently had problems with the Aida and Figaro series. However, in 2011, because about 75% of the total column stock area was steamed, the overall percentage of the 12.0 million column stocks grown which was affected by this problem was probably no greater than 5%. For those growers who had not steamed but grew Aida and Figaro, this was a very serious problem, with some crops showing between 50 and 90% of stems affected.
- There was appreciation amongst both the main propagator and the breeder that Aida and Figaro varieties are weaker-rooted and would therefore be prone to problems on non-steamed soil. This also led to the conclusion that growers and propagators should work more closely together to match the choice of varieties grown with the conditions in which they will be produced, especially with reference to sterilisation techniques.
- The problems observed in the Aida and Figaro varieties took the form of poor root development, lack of vigour (leading to stems of unmarketable quality), wilting and, in some cases, total plant collapse and death. In such cases *Pythium* was consistently isolated from the affected plants, and it is believed this disease would have been a contributing factor to this problem.
- The observations listed above resulted directly in the increase in steaming and reduction of Basamid use in 2012, as outlined above (second bullet point).
- *Fusarium* is still a potentially major problem on some nurseries, especially, but not exclusively, on sites with a history of the disease. In some glasshouses this was still the case, even where the soil had been steamed prior to planting, indicating that steaming does not always control *Fusarium*.
- In 2011, as in previous years, *Fusarium* occurred mainly in the later-planted crops, and in two varieties in particular, Francesca and Centum Deep Blue, which were very badly infected. Of the total 12.0 million stems grown, only a small percentage of the total was lost through *Fusarium*, perhaps up to 5%. However, looking at the susceptible varieties in isolation, about 20% were typically affected, with wide

variation from nursery to nursery - negligible losses in some cases through to losses in excess of 50% in others.

- In 2012 *Fusarium* was again troublesome on Francesca and Centum Deep Blue. Deborah was again freely available from the propagator in 2012, and was shown to be highly susceptible to *Fusarium*, as had been reported by growers before the 2011 survey. Surprisingly, Fedora Deep Rose also suffered from moderate to severe *Fusarium* infection on some nurseries: previously this variety had not been considered particularly susceptible.
- In 2012 problems were also seen in Figaro (both Light Rose and Lilac), which initially suggested *Rhizoctonia* infection. This problem occurred on scattered, random plants, rather than in patches, throughout the whole planting of a batch of Figaro, the symptoms showing within two weeks of planting. The problem was first observed in late-February - very early in the season. Laboratory tests identified that the infection was in fact caused by a strain of *Fusarium* that showed up as a yellow culture on agar plates, rather than the normal red culture seen when *Fusarium* is cultured from column stocks. No more than 1 or 2% of a batch was affected, and, unlike 'traditional' *Fusarium* on column stocks, it did not seem to spread to adjacent plants.
- As the season progressed, more and more cases of this new 'yellow' *Fusarium* (as it became known in the industry) became evident and there was a suspicion among growers that the disease had been brought in with the seedlings. However, this could not be proven because the problem always remained at a very low percentage and did not seem to spread beyond the initially infected plants, so it did not become a major issue; this problem did not recur in the 2013 season.
- There was universal agreement among growers that the current varieties flower more unevenly than they did a decade or so ago. It is now necessary to pick over them two or three times, rather than having a one-off pick.
- The need to ensure good seed selection and stock maintenance to give a potentially more even crop seems to have been adopted by growers, propagators and breeders alike.
- The main propagator's decision to move from glue-plugs to loose-fill plugs seems to have been a positive move, with most growers agreeing that initial plant establishment has been better with loose-fill plugs than in the glue-plugs used in previous years.
- However, there was universal agreement that the loose-fill plug needs to be made more stable in order to facilitate better gapping-up in the trays and planting on the

nursery. This has been addressed by the main propagator, who installed a new filling machine and conducted a number of trials with the new plug prior to the main 2012 production period.

Table 7. Summary of problems encountered in 2011 survey

Grower and house	Glass-house type	Sterilis-ation technique	Sterilis-ation timing	Problem identified	Varieties affected	Level* of infection	Notes
Grower 1 House 1	New Venlo	Dry steam	2 weeks before planting	Fusarium	Francesca	Low	Very bad *Fusarium* in 2010
Grower 1 House 2	New Venlo	Dry steam	2 weeks before planting	Fusarium	Francesca, Centum Deep Blue, and others	Medium Medium Low	Very bad *Fusarium* in 2010
Grower 1 House 3	Old Venlo	Dry steam	2 weeks before planting	Fusarium	Francesca, Centum Deep Blue	Medium Very severe	Aida Blue next to Centum hardly touched. 1st round OK
Grower 1 Tunnel 1	Spanish tunnel	Dry steam	2 weeks before planting	Fusarium	Francesca, Centum Deep Blue	Severe Severe	Troublesome in recent years
Grower 1 Tunnel 2	Spanish tunnel	Dry steam	2 weeks before planting	Fusarium	Francesca, Centum Deep Blue	Severe Severe	Troublesome in recent years
Grower 2 House 1	Old Venlo	Basamid	Mid-October	Pythium	Figaro Lavender, Aida White	Severe Severe	Similar problems in previous years
Grower 2 House 2	Old Venlo	Basamid	Mid-October	Pythium	Figaro Lavender, Aida White.	Severe Severe	Similar problems in previous years
Grower 2 House 3	Old Venlo	Basamid	Mid-October	Pythium	Figaro Lavender, Aida White	Medium Medium	-
Grower 3 House 1	Modern Venlo	Basamid	Autumn	Pythium	Aida White, Aida Lavender, Aida Blue, Fantasy Deep Blue, Fantasy White	Severe Severe Severe Severe Severe	Similar problem in this house last year
Grower 3 House 2	Old Venlo	Basamid	Autumn	Pythium	Fantasy Lavender, Aida White	Severe Severe	Similar problem in this house last year
Grower 4 House 1	Old wide-span	Wet steam	4 to 6 weeks before planting	Poor growth	Carmen Yellow	n.a.	Similar to growers 5 and 6

Grower 5 House 1	Modern Venlo	Dry steam	2 weeks before planting	Poor growth	Carmen Yellow	n.a.	Similar to growers 4 and 6
Grower 6 Several ’new‘ houses	New Venlo	Wet steam	Autumn	Poor growth	Carmen Yellow	n.a.	Similar to growers 4 and 5
Grower 6 Old house 1	Old Venlo	None	n.a.	Pythium	Aida White, Figaro Lavender	Medium Medium	-
Grower 6 Old house 2	Old Venlo	None	n.a.	Fusarium	Francesca	Medium	-
Grower 7 Numerous houses.	Old Venlo	None	n.a.	Pythium	Aida Lavender, Figaro Rose Light	Medium Medium	Just as bad as growers 2 and 3 Basamid area.
Grower 8 House 1	Old Venlo	None	n.a.	Pythium	Aida White, Figaro Lavender, Light Rose	Severe Severe Severe	These varieties also troublesome in 2010

* Low, up to 5%; medium, up to 25%, severe, up to 50%, and very severe, over 50%

Table 8. Summary of problems encountered in 2012 survey

Grower and house	Glass-house type	Sterilis-ation technique	Sterilis-ation timing	Problem identified	Varieties affected	Level* of infection	Notes
Grower 1 House 2	New Venlo	Dry steam	2 weeks before planting.	Fusarium	Mainly Fedora Deep Rose	Medium	No problems in most other varieties
Grower 1 House 3	Old Venlo	Dry steam	2 weeks before planting	’Yellow‘ *Fusarium*	Figaro Lavender, Figaro Light Rose	Low Low	-
Grower 1 Tunnel 1	Spanish tunnel	Dry steam	2 weeks before planting	Fusarium	Most varieties affected to some degree	Very severe	Has been troublesome in recent years
Grower 1 Tunnel 2	Spanish tunnel	Dry steam	2 weeks before planting	Fusarium	Most varieties affected to some degree	Very severe	Has been troublesome in recent years
Grower 3 House 1	Modern Venlo	Steam	Autumn	‘*Pythium* – type’ symptoms	Most varieties affected	Severe	No problems in the 1st round. Cause of the problem in 2nd round could not be determined despite

							numerous laboratory tests
Grower 5 House 1	Modern Venlo	Dry steam	2 weeks before planting	Poor growth	Carmen Yellow	n.a.	Similar to grower 6
Grower 6 Numerous ’new‘ houses	New Venlo	Wet steam	Autumn	Poor growth	Carmen Yellow, Phantom Cream	n.a.	-
Grower 6 Numerous ‘new’ houses	New Venlo	Wet Steam	Autumn	’Yellow‘ Fusarium	Mainly Figaro Lavender, Figaro Rose Light	Low Low	-
Grower 7 Numerous houses	Old Venlo	Basamid	Autumn	’Pythium’	Aida Blue	Low	-
Grower 9 Various houses	Old Venlo and poly tunnels	Dry steam	2 weeks prior to planting	Fusarium	Mainly Fedora Deep Rose, Deborah	Low to Severe Low to Severe	-

* Low, up to 5%; medium, up to 25%, severe, up to 50%, and very severe, over 50%

Samples of diseased plants were sent to the STC Plant Clinic for diagnosis where necessary and the positive results for *Pythium* are summarised in Table 9 by cultivar and sterilisation method. In addition to these samples a number of similar problems were observed on other nurseries that had not steam-sterilised, but the budget did not allow for further samples to be tested.

No *Pythium*-type problems were detected on crops that had been steam-sterilised, even in situations where the soil structure was poor or the crop was waterlogged (e.g. because of leaking gutters). From the laboratory results and discussions with plant pathologists, as well as from the observed improvements in crop performance after the application of an appropriate *Pythium* fungicide, it would appear that *Pythium* is playing a more important role than had been previously appreciated. However, there are several anomalous results that should be noted. In some samples of wilted plants with obviously discoloured roots, laboratory tests yielded only trace levels of *Pythium* or none at all. In many cases these plants had been treated with a *Pythium*-specific fungicide. In order to investigate further, samples of wilted stock Figaro Lavender were taken at the same nursery both from an area treated with Filex and an untreated area. Laboratory results from these samples showed “consistent *Pythium* sp.” from the untreated sample, but only “very low (trace) levels of

Pythium sp." from the Filex-treated sample. These results suggest that *Pythium*-specific fungicides are having a suppressive effect on the laboratory cultures.

On some samples, *Fusarium* was also detected on the roots, though no vascular staining was seen and the samples did not show classic wilt-like symptoms. It was assumed that these *Fusarium* strains were not pathogenic. However, specific pathogenicity tests did show that this strain had the ability to infect vascular tissue, but did not produce wilt symptoms or plant collapse.

In addition to the *Pythium* and *Fusarium* problems described above, some growers also experienced poor establishment and slow growth of stock Carmen Yellow, both in 2011 and 2012. Most of the crop was eventually marketable, but was very uneven and 10 to 14 days behind other varieties in the same house. However this was by no means universal, and occurred only on a small number of plantings on three nurseries. No explanation has so far been found to explain the problem adequately.

In the light of the 2011 survey findings, most growers had either decided to steam the soil prior to planting, or to move away from growing the Aida and Figaro families, hence the incidence of *Pythium*-type symptom was very low in 2012. However, some growers did plant a trial tray of these varieties among their main crop and, as expected, wilting and poor growth were still evident, even though the surrounding varieties showed no symptoms.

Both the 2012 survey work and grower and pot trials showed that *Pythium* does not play as major a role as suspected, the samples collected seeming to be weakly pathogenic at most. The addition of *Pythium*-specific products, both chemical and biological, in the grower trial did not reduce the poor rooting associated with these varieties: the only improvement came from the addition of spent mushroom compost. The issues with the Figaro and Aida families therefore seem to be genetic, a suggestion confirmed by variety trials undertaken at the CFC in 2012, where some coded varieties performed very poorly in non-steamed soils and further investigation showed them to have Figaro in their parentage.

Table 9. Incidence of *Pythium* cultured-out in laboratory tests in relation to variety and sterilisation method

Date	Variety	Disease identified	Sterilisation technique
15 March 2011	Aida White	Pythium	Basamid
23 March 2011	Aida Blue	Pythium	Basamid
23 March 2011	Figaro Lavender	Pythium	Basamid
31 March 2011	Aida White	Pythium	Basamid
31 March 2011	Figaro Lavender	Pythium	Basamid
8 April 2011	Aida White	Pythium	Basamid
8 April 2011	Fantasy White	Pythium	Basamid
8 April 2011	Fantasy Deep Blue	Pythium	Basamid
20 May 2012	Figaro Lavender	Pythium	Basamid
20 May 2012	Aida White	Pythium	Non-sterilised
29 June 2012	Aida White	Pythium	Non-sterilised
29 June 2012	Figaro Lavender	Pythium	Non-sterilised

The sterilisation techniques used can be split to four categories, i.e. wet steam, dry steam, Basamid and non-sterilized. Table 10 gives a breakdown of the number of stems grown in each of these categories in 2011 and 2012. There is no universal protocol for steaming soil because this is dependent on soil type, structure, etc., and also the grower's knowledge of how best to manage diseases on their own nursery. All growers are using sheet-steaming, but even then there is a large variation in the amount of time for which each nursery steams an area, ranging from 4 to 6 hours. There seems to be a genuine mistrust of relying on probes to determine when an area has been adequately steamed, with most growers relying on their own gut feeling. The figures in Table 10 reflect the move away from growing in either non-steamed or Basamid-sterilised soil in 2012, compared with 2011, with an increase in steam sterilisation.

Table 10. Number of stems produced under different sterilisation methods

Sterilisation method	Total number of stems	
	2011	2012
Wet steam	3,150,000	4,700,000
Dry steam	5,850,000	7,600,000
Basamid	2,300,000	600,000
Non-sterilised	850,000	negligible

Pythium glasshouse trial

The results of soil analysis are shown in Table 11. The incorporation of paper waste or mushroom compost led to increases in soil pH, P and Mg levels and electrical conductivity (EC). Incorporating mushroom compost also led to increases in K and N levels.

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Table 11. Soil analysis results for the *Pythium* trial (figures in brackets are nutrient indices)

Plot	Treatment	pH	P (mg/l)	K (mg/l)	Mg (mg/l)	N (mg/l)	EC (µS)
65	Before paper waste incorporation	6.7	35 (3)	327 (3)	209 (4)	55 (2)	2605 (2)
65	After paper waste incorporation	7.7	44 (3)	310 (3)	234 (4)	40 (1)	2716 (4)
65	End of trial	7.4	48 (4)	282 (3)	222 (4)	57 (2)	2879 (5)
71	Before mushroom compost incorporation	7.2	32 (3)	247 (3)	165 (3)	55 (2)	2482 (2)
71	After mushroom compost incorporation	8.2	97 (5)	1080 (6)	373 (6)	59 (2)	3624 (7)
71	End of trial	7.7	123 (6)	1080 (6)	390 (6)	164 (4)	3814 (8)

Stem lengths and weights were assessed as these are key determinants of the marketability of cut-flowers. Stem lengths were reasonably consistent throughout the trial at about 50cm, though Aida White was consistently slightly longer than Figaro Lavender (Figure 5). The plants in two treatments (13 and 15), of which the common feature was the application of chitin (mushroom compost), were taller than the rest. Plants in two other treatments, HDC F45 (treatment 7) and Paraat (treatment 9), were shorter than the rest. Analysis of variance confirmed that both soil treatment and cultivar effects were significant (at $P<0.05$), with no significant interaction between the two factors (Table 12).

In contrast to lengths, stem weights were more variable (Figure 6). Stems of Figaro Lavender were notably heavier than those of Aida White. As in the case of stem lengths, weights were greater in the two chitin (mushroom compost) treatments (13 and 15). Stem weights, however, were lower in treatments 12 and 14 which involved the application of lignum (paper waste). For stem weights, analysis of variance showed that both soil treatment and cultivar effects were significant (at $P<0.001$), while there was no significant interaction between the factors (Table 13).

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Figure 5. Plants from the mushroom compost + trianum plot compared with trianum only (left) and plants from mushroom compost + trianum plot compared to control (right).

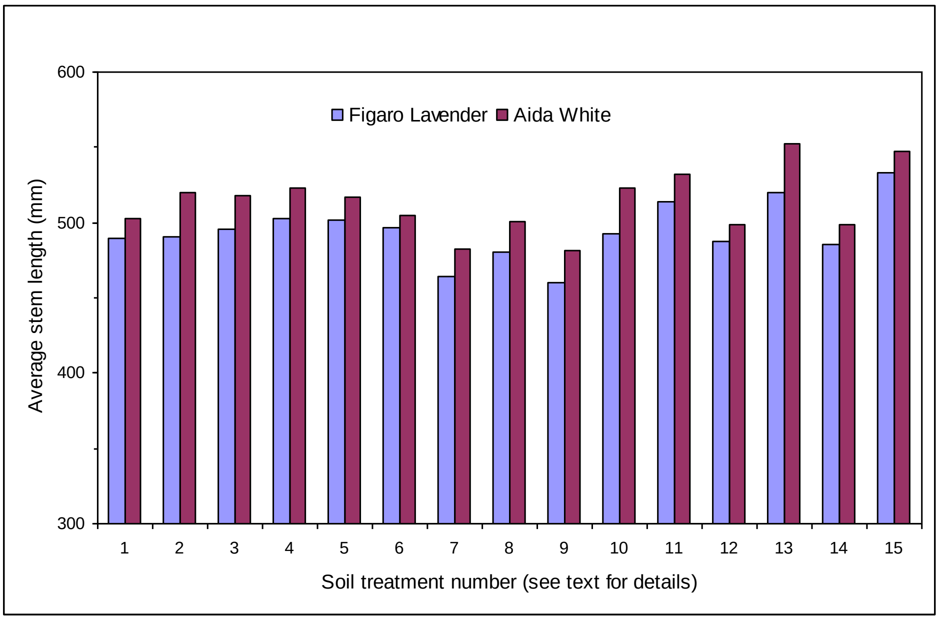

Figure 6. Stem length in plots of two column stocks varieties subjected to a range of soil treatments (for details, see text and Table 12). Values are the means of four replicate plots.

Table 12. Stem length in plots of two column stocks varieties subjected to a range of soil treatments. Treatment and marginal means are also shown, along with the least significant differences (LSD) at the 5% level of probability. The AoV table is shown below.

	Soil treatment	Stem length (mm)		
		Figaro	**Aida**	**Marginal means**
1	Untreated	489.3	502.3	495.8
2	Untreated	491.0	519.8	505.4
3	Trianum - propagation only	495.5	518.3	506.9
4	Trianum - 0.6g/m^2 +propagation	502.5	523.3	512.9
5	Trianum - 1.2g/m^2 + propagation	501.5	517.3	509.4
6	Trianum - 1.2g/m^2	496.8	504.5	500.6
7	HDC F45 - 0.6g/m^2	464.0	482.0	473.0
8	Subdue - 0.0625ml/m^2	480.8	501.0	490.9
9	Paraat - 0.3g/m^2	460.0	481.5	470.8
10	Prestop - 5g/m^2	492.5	522.8	507.6
11	Serenade -1ml/m^2	513.8	532.0	522.9
12	Lignum + Trianum at 1.2g/m^2 + propagation	487.3	498.3	492.8
13	Chitin + Trianum at 1.2g/m^2 + propagation	519.8	552.5	536.1
14	Lignum + Prestop at 5g/m^2	485.8	499.0	492.4
15	Chitin + Prestop at 5g/m^2	533.0	547.3	540.1
		LSD (5%) = 25.26		LSD (5%) = 25.26
	Marginal means for cultivar	494.2	513.4	
		LSD (5%) = 69.17		

Source of variation	SS	df	MS	F	P	Significance
Soil treatment	43228.586	14	3087.756	2.556	0.004	**
Cultivar	11080.330	1	11080.330	9.172	0.003	**
Interaction	1457.846	14	104.132	0.086	1.000	ns
Residual	108725.208	90	1208.058			
Total	164491.970	119				

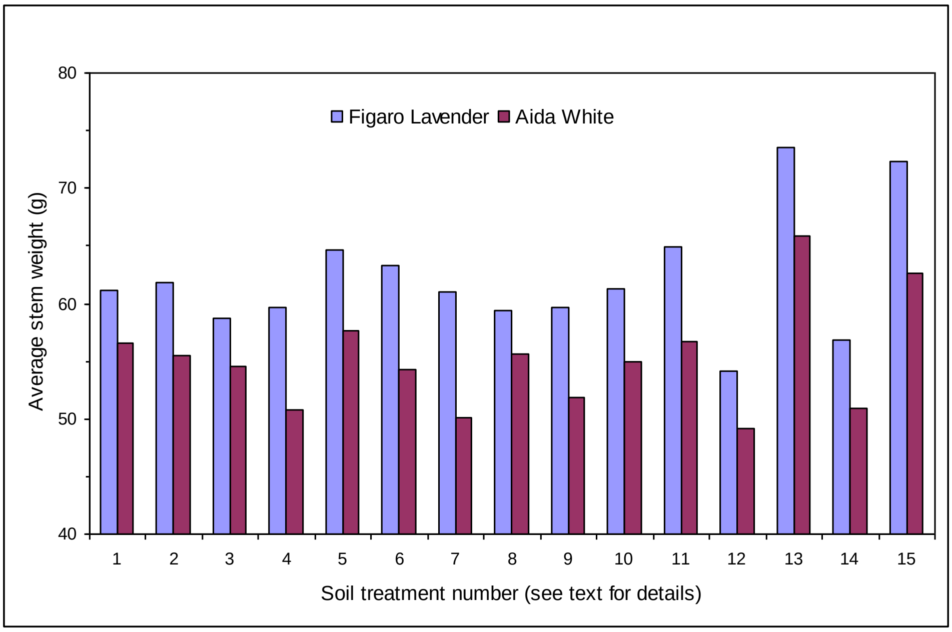

Figure 7. Stem weight in plots of two column stocks varieties subjected to a range of soil treatments (for details, see text and Table 13). Values are the means of four replicate plots.

Table 13. Stem weight in plots of two column stocks varieties subjected to a range of soil treatments. Treatment and marginal means are also shown, along with the least significant differences (LSD) at the 5% level of probability. The AoV table is shown below.

	Soil treatment	Stem weight (g)		
		Figaro	**Aida**	**Marginal means**
1	Untreated	61.2	56.6	58.9
2	Untreated	61.8	55.4	58.6
3	Trianum - propagation only	58.8	54.6	56.7
4	Trianum - 0.6g/m^2 + propagation	59.7	50.8	55.2
5	Trianum - 1.2g/m^2 + propagation	64.7	57.7	61.2
6	Trianum - 1.2g/m^2	63.4	54.3	58.8
7	HDC F45 - 0.6g/m^2	61.0	50.1	55.6
8	Subdue - 0.0625ml/m^2	59.4	55.6	57.5
9	Paraat - 0.3g/m^2	59.7	51.9	55.8
10	Prestop - 5 g/m^2	61.2	55.0	58.1
11	Serenade -1ml/m^2	65.0	56.7	60.9
12	Lignum + Trianum at 1.2g/m^2 + propagation	54.1	49.2	51.6
13	Chitin + Trianum at 1.2g/m^2 + propagation	73.6	65.8	69.7
14	Lignum + Prestop at 5g/m^2	56.8	50.9	53.8
15	Chitin + Prestop at 5g/m^2	72.4	62.7	67.5
		LSD (5%) = 5.06		LSD (5%) = 5.06
	Marginal means for cultivar	62.2	55.1	
		LSD (5%) = 13.86		

Source of variation	SS	df	MS	F	P	Significance
Soil treatment	2551.441	14	182.246	3.757	<0.001	***
Cultivar	1476.307	1	1476.307	30.436	<0.001	***
Interaction	127.515	14	9.108	0.188	0.999	ns
Residual	4365.478	90	48.505			
Total	8520.740	119				

Fusarium glasshouse trial

The results of soil analysis are shown in Table 14. Soil pH was little affected by the incorporation of any of the materials used. The incorporation of mushroom compost led to increases in EC and levels of K, Mg and N. The incorporation of bark led to an increase in N level (the effect on EC and Mg level was inconsistent). There were no changes in any of these levels following the incorporation of paper waste.

Table 14. Soil analysis results for the *Fusarium* trial (figures in brackets are nutrient indices)

Plot	Treatment	pH	P (mg/l)	K (mg/l)	Mg (mg/l)	N (mg/l)	EC (µS)
12	Before bark incorporation	7.4	142 (7)	400 (3)	173 (3)	17 (0)	2838 (5)
12	After bark incorporation	6.9	135 (6)	510 (4)	214 (4)	169 (4)	3057 (6)
12	End of trial	7.1	152 (7)	442 (4)	239 (4)	55 (2)	2860 (5)
37	Before paper waste incorporation	7.5	135 (6)	380 (3)	151 (3)	41 (1)	2757 (4)
37	After paper waste incorporation	7.6	105 (6)	354 (3)	156 (3)	34 (1)	2719 (4)
37	End of trial	7.7	133 (6)	350 (3)	163 (3)	18 (0)	2726 (4)
63	Before mushroom compost incorporation	7.6	125 (6)	374 (3)	161 (3)	32 (1)	2705 (3)
63	After mushroom compost incorporation	7.4	137 (6)	1240 (6)	291 (5)	49 (1)	3878 (8)
63	End of trial	7.6	164 (7)	1060 (6)	282 (5)	134 (3)	3527(7)
98	Before bark incorporation	7.7	119 (6)	339 (3)	134 (3)	15 (0)	2761 (4)
98	After bark incorporation	7.3	118 (6)	345 (3)	142 (3)	89 (2)	2766 (4)
98	End of trial	7.3	146 (7)	339 (3)	181 (4)	42 (1)	2686 (3)
107	Before mushroom comp incorporation	7.7	125 (6)	327 (3)	132 (3)	17 (0)	2735 (4)
107	After mushroom compost incorporation	7.4	145 (7)	1060 (6)	231 (4)	34 (1)	3745 (8)
107	End of trial	7.7	165 (7)	960 (6)	264 (5)	43 (1)	3371 (7)
114	Before paper waste incorporation	7.7	122 (6)	333 (3)	136 (3)	20 (0)	2855 (5)
114	After paper waste incorporation	7.9	118 (6)	304 (3)	122 (3)	17 (0)	2520 (2)
114	End of trial	7.7	138 (6)	304 (3)	127 (3)	27 (1)	2554 (2)

The striking result of this experiment was that only a few treatments or plots produced viable stems (Figure 7). Only three treatments – those which included an application of bark (treatments 20, 21 and 24) – produced a reasonable number of stems. Concurrent treatment with either Trianum or Prestop (treatments 20 and 21) gave no advantage compared with using bark alone. Some other plots sporadically produced a small number of stems, particularly treatments 4 (Trianum applied at propagation), 15 (Serenade) and 22 (soak of plug trays in T34), but the majority, including all untreated (control) plots, produced none. In general, variety Francesca produced more stems than Centum Deep Blue.

The analysis of variance (Table 15) confirmed that the effect of soil treatment was significant (at $P<0.001$), while the effects of cultivar, and of the interaction between the two factors, were not. Further analysis using square root-transformed data ($\sqrt{}$(value+0.5)) (data not shown) confirmed these conclusions about soil treatment, though it showed the effect of cultivar to be significant (at $P<0.05$), so confirming the suggestion that variety Francesca was the somewhat more robust of the two.

There was a distinct edge effect in the trial, with all the plants at the side of the glasshouse wall showing much better growth and less *Fusarium* than others. Despite being viewed by a wide range of people, no satisfactory explanation was developed. However, the apparently better performance of treatments 4 (Trianum application at propagation) and 15 (Serenade) appear to be artefacts of this edge effect: unlike the case of the bark plots, better performance was not seen throughout all of these plots.

Another anomaly in the trial was the fact that about half of the seedlings planted into the mushroom compost-treated plots died within 2 weeks, but those that did survive showed a greater resistance to *Fusarium*. The crop was so delayed that very few of the flowers were ready by the time the trial was completed.

The *Fusarium* score for each plot is shown in the Figure 8. The plots of only three treatments – the same as seen in the results above – had scores exceeding 3.0, i.e. they produced viable flowers though still showing symptoms of disease. Other plots, including the controls, gave scores about 2, meaning that although the majority of plant tissues remained green, there were symptoms of disease. Analysis of variance on these data confirmed that the effect of soil treatment was significant (at $P<0.001$), while the effects of cultivar, and of the interaction between the two factors, were not (Table 16).

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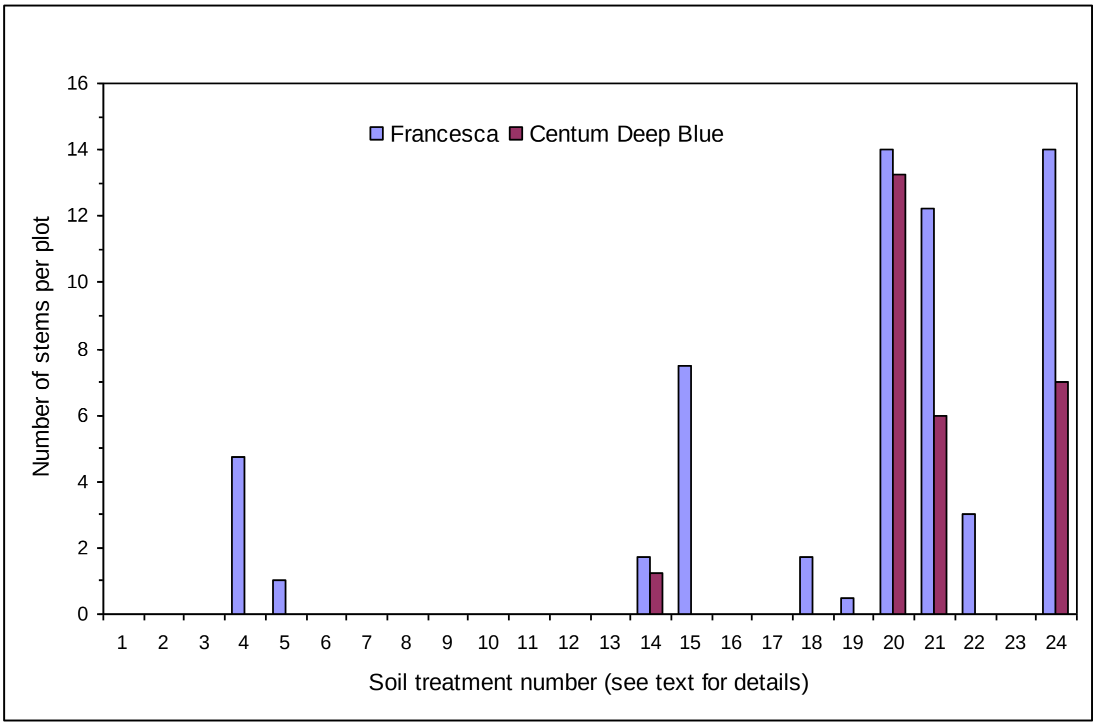

Figure 8. The number of viable stems in plots of two column stocks varieties subjected to a range of soil treatments (for details, see text and Table 15). Values, the means of four replicates, are the number of viable stems per plot of 64 plants.

Table 15. The number of viable stems in plots of two column stocks varieties subjected to a range of soil treatments. Treatment and marginal means are also shown, along with the least significant differences (LSD) at the 5% level of probability. The AoV table is shown below.

	Soil treatment	**Viable stems per plot**		
		Francesca	**Centum**	**Marginal means**
1	Untreated	0.0	0.0	0.0
2	Untreated	0.0	0.0	0.0
3	Untreated	0.0	0.0	0.0
4	Trianum propagation only	4.8	0.0	2.4
5	Trianum - 6kg/ha + propagation	1.0	0.0	0.5
6	Trianum - 12kg/ha + propagation	0.0	0.0	0.0
7	Trianum - 12kg/ha	0.0	0.0	0.0
8	Exp. *Trichoderma* propagation only	0.0	0.0	0.0
9	Exp. *Trichoderma* - 4kg/ha +propagation	0.0	0.0	0.0
10	Exp. *Trichoderma* - 6kg/ha	0.0	0.0	0.0
11	Octave - 2g/L	0.0	0.0	0.0
12	Signum - 1.35kg/ha	0.0	0.0	0.0
13	Switch - 0.8kg/ha	0.0	0.0	0.0
14	Prestop - 100g/20L	1.8	1.3	1.5
15	Serenade - 10L/ha	7.5	0.0	3.8
16	Lignum + Trianum - 12kg/ha	0.0	0.0	0.0
17	Lignum + Prestop - 100g/20L	0.0	0.0	0.0
18	Chitin + Trianum - 12kg/ha	1.8	0.0	0.9
19	Chitin + Prestop- 100g/20L	0.5	0.0	0.3
20	Bark + Trianum - 12kg/ha	14.0	13.3	13.6

21	Bark + Prestop 100g/20L	12.3	6.0	9.1
22	T34 soak - 0.01g/L (plug)	3.0	0.0	1.5
23	Mushroom	0.0	0.0	0.0
24	Bark	14.0	7.0	10.5
		LSD (5%) = 3.17		LSD (5%) = 3.17
	Marginal means for cultivar	2.5	1.1	
		LSD (5%) = 10.97		

Source of variation	SS	Df	MS	F	P	Significance
Soil treatment	2590.167	23	112.616	3.670	<0.001	***
Cultivar	90.750	1	90.750	2.958	0.088	ns
Interaction	271.250	23	11.793	0.384	0.995	ns
Residual	4418.500	144	30.684			
Total	7370.667	191				

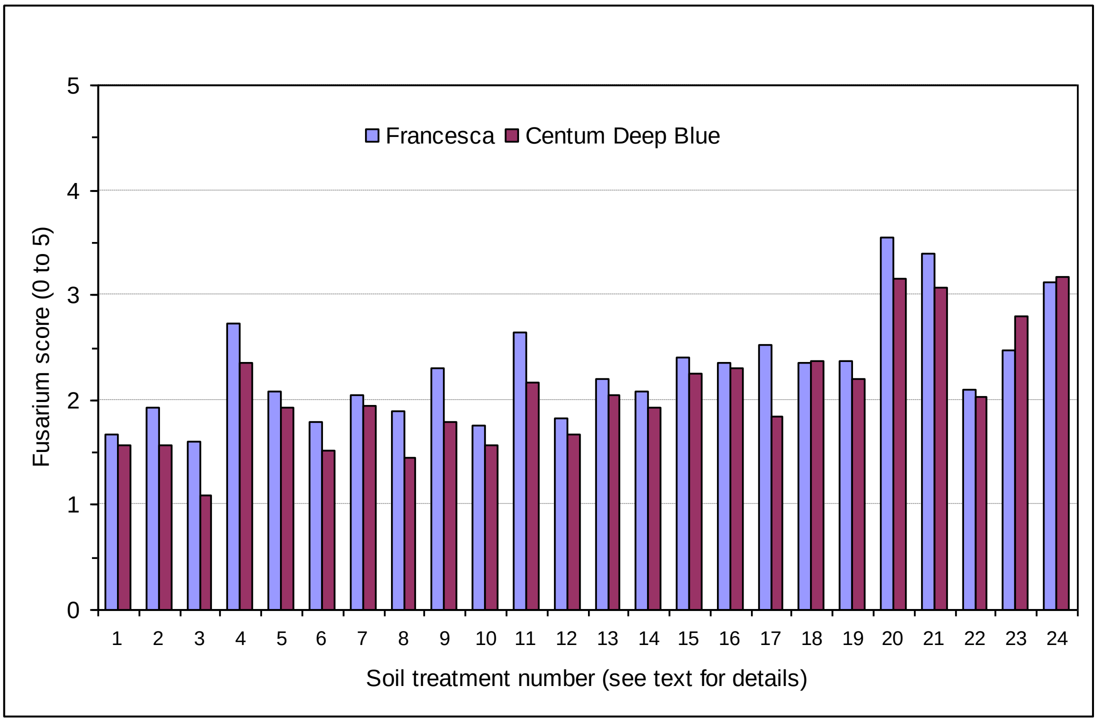

Figure 9. *Fusarium* scores in plots of two column stocks varieties subjected to a range of soil treatments (for details, see text and Table 16). Values are the means of four replicate plots.

Table 16. *Fusarium* scores in plots of two column stocks varieties subjected to a range of soil treatments. Treatment and marginal means are shown, along with the least significant differences (LSD) at the 5% level of probability. The AoV table is shown below.

	Soil treatment	*Fusarium* score		
		Francesca	**Centum**	**Marginal means**
1	Untreated	1.7	1.6	1.6
2	Untreated	1.9	1.6	1.8
3	Untreated	1.6	1.1	1.4
4	Trianum propagation only	2.7	2.4	2.5
5	Trianum - 6kg/ha (+ prop)	2.1	1.9	2.0
6	Trianum - 12kg/ha (+ prop)	1.8	1.5	1.7
7	Trianum - 12kg/ha	2.1	2.0	2.0
8	Exp. *Trichoderma* propagation only	1.9	1.5	1.7
9	Exp. *Trichoderma* - 4kg/ha (+prop)	2.3	1.8	2.1
10	Exp. *Trichoderma* - 6kg/ha	1.8	1.6	1.7
11	Octave - 2g/l	2.7	2.2	2.4
12	Signum - 1.35kg/ha	1.8	1.7	1.8
13	Switch - 0.8kg/ha	2.2	2.1	2.1
14	Prestop - 100g/20L	2.1	1.9	2.0
15	Serenade - 10L/ha	2.4	2.3	2.3
16	Lignum + Trianum - 12kg/ha	2.4	2.3	2.3
17	Lignum + Prestop - 100g/20L	2.5	1.9	2.2
18	Chitin + Trianum - 12kg/ha	2.4	2.4	2.4
19	Chitin + Prestop- 100g/20L	2.4	2.2	2.3
20	Bark + Trianum - 12kg/ha	3.6	3.2	3.4
21	Bark + Prestop 100g/20L	3.4	3.1	3.2

22	T34 soak - 0.01g/L Plug	2.1	2.0	2.1
23	Mushroom	2.5	2.8	2.6
24	Bark	3.1	3.2	3.2
		LSD (5%) = 0.48		LSD (5%) = 0.48
	Marginal means for cultivar	2.5	1.1	
		LSD (5%) = 1.67		

Source of variation	SS	df	MS	F	P	Significance
Soil treatment	49.542	23	2.154	3.032	<0.001	***
Cultivar	2.385	1	2.385	3.358	0.069	ns
Interaction	2.212	23	0.096	0.135	1.000	ns
Residual	102.295	144	0.710			
Total	156.435	191				

Pythium pot trial

Pot studies were undertaken using two isolates of *Pythium* sp., 250 and 257, and some examples are illustrated in Figure 10.

Figure 10. View of one of the replicated blocks of the *Pythium* study using isolates 250 (above) and 257 (below)

Compared with the controls, all drench treatments had a substantial negative effect on germination (Figure 10, Table 17). This was more pronounced using isolate 257, where some of the treatments, particularly Prestop and Trianum, resulted in a decrease in the number of emerged seedlings by up to 70% compared with the non-inoculated control. AoV showed that both treatment and isolate effects were significant at the $P<0.001$ level. The interaction between the two factors was not significant.

The background level of post-emergence damping-off was <1% in the un-inoculated control plants, and following inoculation with *Pythium* (inoculated controls) the incidence of damping-off increased only slightly, to <4% of plants (Figure 12, Table 18). Following adding the *Pythium* cultures to the substrate, they could not be re-isolated from the affected plants. This suggests that the isolates were at best weak root pathogens, or even opportunistic fungi.

None of the applied treatments were found to be effective at controlling *Pythium* when compared with the inoculated control. In fact, the increase in post-emergence damping-off following drench treatments was striking; with the exception of two treatments where infection levels remained around only 2% (Previcur Energy and Trianum used with isolate 257), all other treatments increased damping-off strikingly, by up to 22%. On the whole, infection was greater where isolate 250 had been used. The most notable increases were seen using Serenade and HDC F132 (using isolate 250) and HDC F128 (using isolate 257). At present, we are unable to explain this, other than by suggesting that these products have either weakened the plants, making them more susceptible, or have modified the ecological balance in the soil, increasing susceptibility. AoV showed that the effect of isolate was significant at the $P<0.01$ level and the effect of drench treatments was weaker ($P<0.05$); the interaction between the two factors was not significant.

Plant vigour was also scored. With the exception of treatment with Plant Trust, the vigour of all plots (control and treated) were around 60–70%: where Plant Trust had been used vigour increased to almost 100%, irrespective of the *Pythium* isolate applied. However, this may have been a result of the presence of additional nutrients in the product formulation, rather than any differential impact of the *Pythium* compared with the other treatments.

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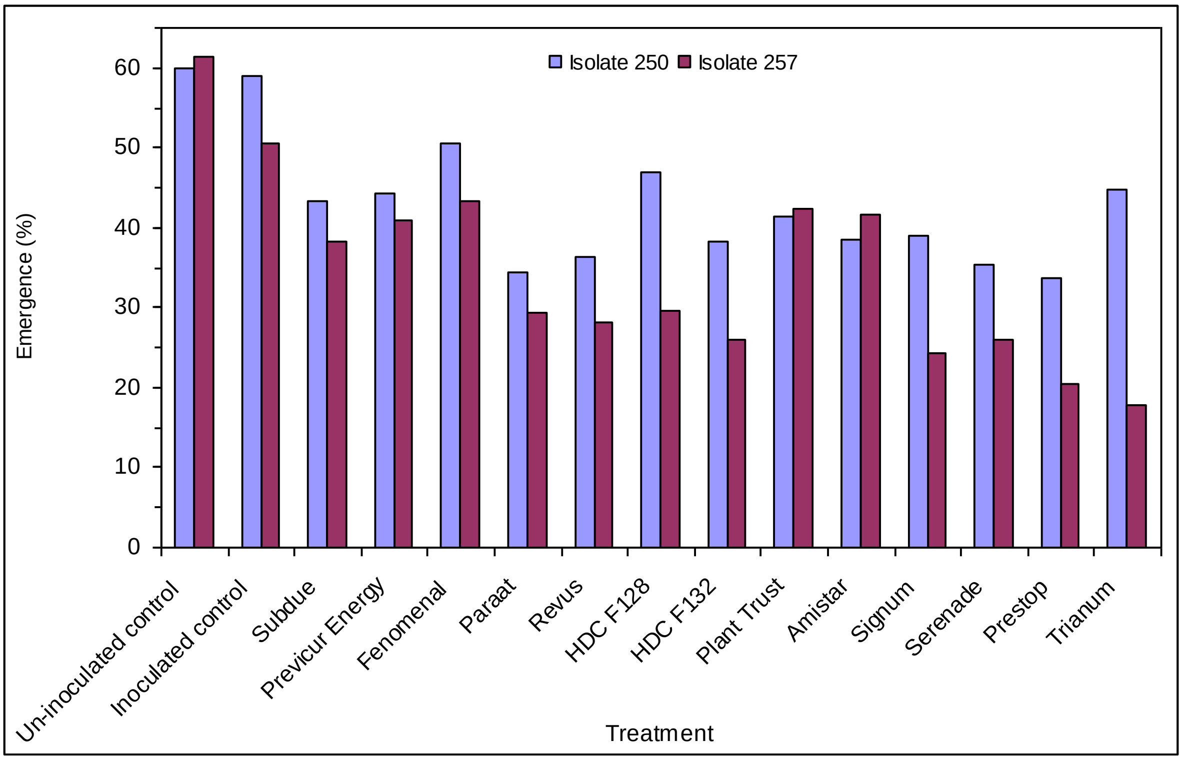

Figure 11. Mean % emergence of column stock seedlings at the 100% emergence stage following incorporation of *Pythium* isolate 250 or 257 into the growing medium and subsequent drenching with the treatments indicated. See also Table 17.

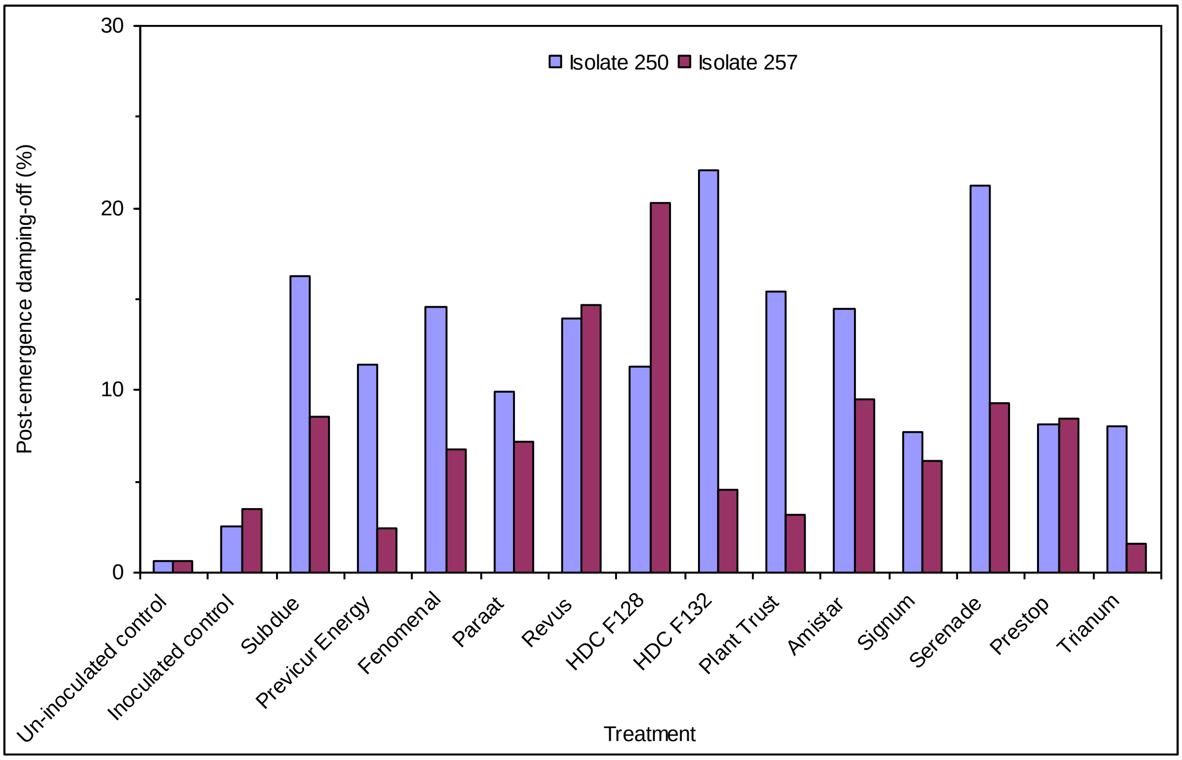

Figure 12. Mean % post-emergence damping-off of column stock following incorporation of *Pythium* isolate 250 or 257 into the growing medium and subsequent drenching with the treatments indicated. See also Table 18.

Table 17. Mean % emergence of column stock seedlings at the expected 100% emergence stage following incorporation of *Pythium* isolate 250 or 257 into the growing medium and subsequent drenching with the treatments indicated. Treatment and marginal means are also shown, along with the least significant differences (LSD) at the 5% level of probability. The AoV table is also shown.

	Drench treatment	% Emergence		
		Isolate 250	Isolate 257	Marginal means
1	Un-inoculated control	60.0	61.5	60.8
2	Inoculated control	59.0	50.5	54.8
3	Subdue	43.3	38.3	40.8
4	Previcur Energy	44.3	41.0	42.6
5	Fenomenal	50.5	43.3	46.9
6	Paraat	34.5	29.3	31.9
7	Revus	36.3	28.3	32.3
8	HDC F128	47.0	29.5	38.3
9	HDC F132	38.3	26.0	32.1
10	Plant Trust	41.5	42.3	41.9
11	Amistar	38.5	41.8	40.1
12	Signum	39.0	24.3	31.6
13	Serenade	35.5	26.0	30.8
14	Prestop	33.8	20.5	27.1
15	Trianum	44.8	17.8	31.3
		LSD (5%) = 6.43		LSD (5%) = 6.43
	Marginal means for cultivar	43.1	34.7	
		LSD (5%) = 17.62		

Source of variation	SS	df	MS	F	P	Significance
Treatment	10210.367	14	729.312	9.303	<0.001	***
Isolate	2116.800	1	2116.800	27.002	<0.001	***
Interaction	1751.200	14	125.086	1.596	0.096	NS
Within	7055.500	90	78.394			
Total	21133.867	119				

Table 18. Mean % post-emergence damping-off of column stock following incorporation of *Pythium* isolate 250 or 257 into the growing medium and subsequent drenching with the treatments indicated. Treatment and marginal means are also shown, along with the least significant differences (LSD) at the 5% level of probability. The AoV table is also shown.

	Drench treatment	% Emergence Isolate 250	Isolate 257	Marginal means
1	Un-inoculated control	0.7	0.6	0.7
2	Inoculated control	2.5	3.4	3.0
3	Subdue	16.2	8.6	12.4
4	Previcur Energy	11.4	2.4	6.9
5	Fenomenal	14.6	6.7	10.7
6	Paraat	10.0	7.2	8.6
7	Revus	14.0	14.6	14.3
8	HDC F128	11.3	20.3	15.8
9	HDC F132	22.0	4.5	13.3
10	Plant Trust	15.4	3.1	9.2
11	Amistar	14.4	9.5	12.0
12	Signum	7.7	6.1	6.9
13	Serenade	21.2	9.3	15.2
14	Prestop	8.1	8.5	8.3
15	Trianum	8.0	1.6	4.8
		LSD (5%) = 6.29		LSD (5%) = 6.29
	Marginal means for cultivar	11.8	7.1	
		LSD (5%) = 17.22		

Source of variation	SS	df	MS	F	P	Significance
Treatment	2281.351	14	162.954	2.175	0.015	*
Isolate	675.677	1	675.677	9.019	0.003	**
Interaction	1243.279	14	88.806	1.185	0.300	NS
Within	6742.176	90	74.913			
Total	10942.483	119				

Fusarium pot trial

The treatments resulted in different seedling survival rates (Figure 12), though all treatments reduced percentage emergence (recorded at the 100% emergence stage) compared with the untreated controls (whether inoculated or not) (Figure 14, Table 19). Percentage emergence in the controls was about 80%, and in the various treatments varied between 55 and 67%. AoV confirmed that the treatment effect was significant (P<0.01).

Figure 13. One of the replicate blocks from the *Fusarium* study showing treatment differences in seedling emergence

Figure 14. A close-up of *Fusarium* wilt from the inoculated control plot.

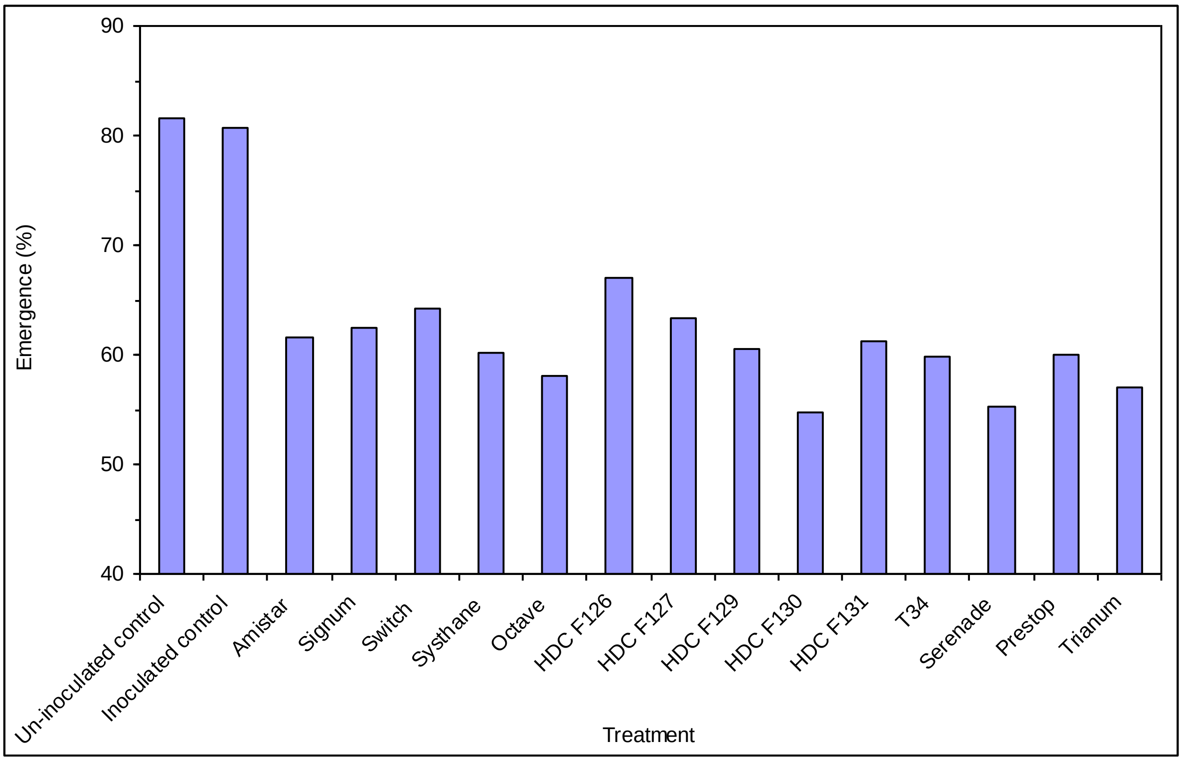

Figure 15. Emergence of column stock seedlings (recorded at the 100% emergence stage) in a range of treatments. See also Table 19.

Following inoculation by *Fusarium oxysporum* f.sp. *matthioli,* vascular wilt (Figure 13) developed rapidly. Ninety percent of the seedlings died in the inoculated control. The non-inoculated control remained disease-free throughout the study. The results showed that only two of the applied treatments, Systhane and Octave, resulted in a significant decrease in *Fusarium* infection. Systhane treatment decreased *Fusarium* infection levels by 32% and Octave provided a much larger, 85% decrease in infection levels, compared with the inoculated control (Figure 15). None of the other experimental treatments appeared to have any significant effect. AoV confirmed that the treatment effect was significant (P<0.001).

No significant differences in plot vigour were observed, nor were any phytotoxic effects seen during the trial. However, 4 weeks after the cessation of the trial severe leaf curling and distortion was observed in several of the Octave-treated plants.

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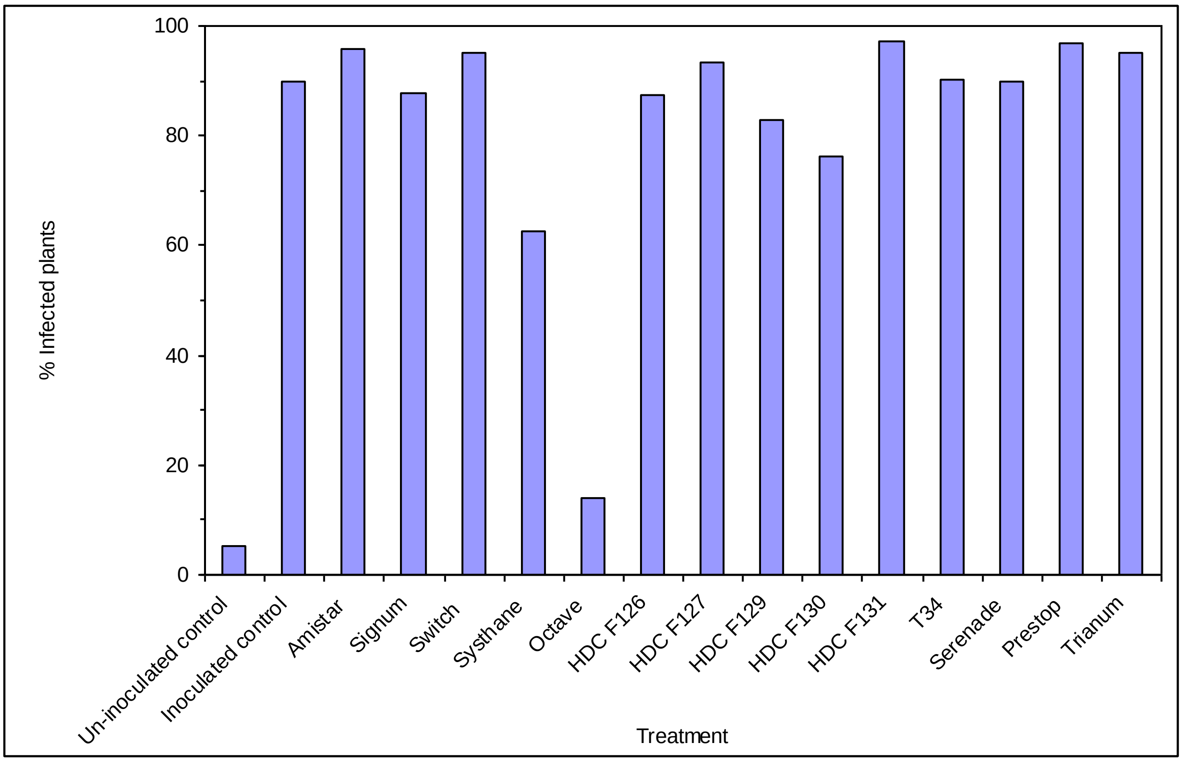

Figure 16. Percentage of plants infected with *Fusarium* 8 weeks post-emergence. See also Table 19.

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Table 19. Mean % emergence (at the 100% emergence stage) and post-emergence infection of column stock seedlings following incorporation of *Fusarium* into the growing medium and subsequent drenching with the treatments indicated. Treatment means are shown, along with the least significant differences (LSD) at the 5% level of probability. The AoV table is also shown.

Treatment	Percentage	
	Emergence	**Infection**
Un-inoculated control	81.5	5.1
Inoculated control	80.8	89.9
Amistar	61.5	95.6
Signum	62.5	87.7
Switch	64.3	95.2
Systhane	60.3	62.5
Octave	58.0	13.9
HDC F126	67.0	87.4
HDC F127	63.3	93.2
HDC F129	60.5	82.9
HDC F130	54.8	76.2
HDC F131	61.3	97.1
T34	59.8	90.2
Serenade	55.3	89.9
Prestop	60.0	97.0
Trianum	57.0	95.2
LSD (5%)	6.67	6.44

Anova - % plant emergence

Source of Variation	SS	df	MS	F	P	Significance
Treatment	3611.938	15	240.796	2.735	0.004	**
Residual	4226.000	48	88.042			
Total	7837.938	63				

Anova - % plant infection

Source of Variation	SS	df	MS	F	P	Significance
Treatment	48620.045	15	3241.336	39.515	<0.001	***
Residual	3937.334	48	82.028			
Total	52557.379	63				

Discussion

The detailed survey work and associated activities during 2011 and 2012 (grower walks, study tours, etc.) was able to provide some explanations and partial solutions to the problems that column stock growers have been experiencing in recent years. It has become clear that not all of the problems have been universal, and that more than one issue needs addressing. Some issues are still ongoing and require additional work to resolve.

The problem of poor rooting and associated discoloured roots, leading to wilting and poor growth, seems to be a universal problem with the Aida and Figaro families where the soil has not been steam-sterilised. Individual growers had been aware for some time that these varieties were troublesome on their nurseries, but had not been aware of how widespread the issue was with other growers. Both the propagator and breeder have subsequently stated that they consider these 'newer' varieties to be potentially troublesome owing to their being weaker-rooted than some of the older varieties. The work in 2011 indicated that *Pythium* was playing an important role associated with the root problems, but this was not conclusive and was investigated further in 2012. The 2012 survey work and trials (both the glasshouse and pot trials) showed that *Pythium* does not seem to play as major a role as suspected, with the samples collected being at most only weakly pathogenic. There is still a question mark over how the routine application of chemicals to control *Pythium* can, mask the symptoms in the laboratory, but the fact that the addition of *Pythium*-specific products, both chemical and biological, in the glasshouse trial did not reduce the poor rooting associated with these varieties, with the only improvement coming from the addition of spent mushroom compost, seems to confirm that *Pythium* is not a major cause of problems. The issues with the Figaro and Aida families therefore seemed to be genetic, a theory backed-up by variety trials undertaken at the CFC in 2012, where some coded varieties performed very poorly in non-steamed soils and further investigation showed them to have Figaro in their parentage.

It is clear that *Fusarium* wilt is still a major problem in column stocks, with some growers experiencing serious losses in 2011 and 2012 despite soil being steamed prior to planting. There are strong varietal differences in susceptibility to *Fusarium*, with Centum Deep Blue and Francesca being particularly troublesome in these years. On one nursery in 2102 a crop of Centum Deep Blue was grown side-by-side with Aida Blue, when the *Fusarium* infection showed a clear 'straight line' infection of the Centum Deep Blue with very little Fusarium showing in the Aida Blue. Opera Deborah is also known to be very susceptible to Fusarium, but, owing to supply issues, very little of this variety was grown in 2011. However, in 2012 Deborah was supplied as normal and was again shown to be susceptible

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to *Fusarium*. In addition to Deborah, Francesca and Centum Deep Blue, Fedora Deep Rose, a variety not previously thought to be troublesome was also susceptible to *Fusarium* in 2012. However, it must be stated that none of the current varieties seem to be resistant to *Fusarium*, and, in the case of very severe disease pressure; all varieties can show some level of infection. This will be further investigated in 2013 when the CFC will undertake a screening trial of varietal susceptibility to *Fusarium* as part of Project PO BOF 002a. Not all nurseries surveyed experienced *Fusarium* problems, but for those that did it was very serious, resulting in considerable crop losses in some houses in both years. In most, but not all cases, *Fusarium* occurred in houses with a history of the disease. It is clear, from both the survey work and 2012 trials, that at the current time there is no commercially available reliable chemical or biological control of *Fusarium*, and in houses with a history of the disease, even steaming is only a partial cure. In the glasshouse trial no treatment, other than the incorporation of composted bark, showed any degree of control of *Fusarium*, and in the pot study at STC there were only two treatments that showed any significant efficacy against *Fusarium*. Systhane showed a slight reduction in infection levels, but the level of control achieved was unacceptable from a commercial perspective.

Octave, on the other hand, showed an 85% decrease in infection levels when compared with the control, and was really the only treatment in the trial demonstrating effective control. However it is important to note that relative to the other treatments, the rate of application of prochloraz-Mn was much higher due to confusion in the rate-of-use information supplied. The increased dose provides the most likely explanation of why this treatment appeared to be so much more effective in controlling *Fusarium*, when compared with the other treatments and would not be an approved method of control on a commercial nursery. In this regard it is quite fortuitous, as it demonstrated that increasing the application rate can potentially help to discriminate between treatments given the lack of differences observed at standard label rates. It may be possible to find other treatments that also provide effective control at higher concentrations, and it may be worthwhile undertaking further pot studies with *Fusarium oxysporum* f.sp. *matthioli.* It is obviously of some concern, however, that some phytotoxicity symptoms were observed with prochloraz-Mn following cessation of the trial, and this needs to be monitored closely in any further studies. Certain issues still remain unresolved, such as the poor growth of Carmen Yellow on a few nurseries in both 2011 and 2012.

The survey has also highlighted the differences in steaming technique that occur from nursery to nursery and this was investigated further in 2012 to try and determine if for example there is any difference in disease control between wet and dry steam. However the 2012 survey work did not show any clear connection between steaming technique and

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incidence of *Fusarium*. The main *Fusarium* risk does seem to be related to variety choice, history of the disease in the individual glasshouses, and the ’quality‘ of steaming, i.e. soil type, structure and moisture status, length of steaming time etc.

The issue of quality of steaming is important because it has become clear that the soil structure and soil moisture status need to be ’right‘ if steaming is going to be effective. Just steaming for longer will not compensate for inadequacies in these factors. More work is needed to enable growers to get the best results from steaming reliably. The disease problems experienced by some growers have lead to an interest in the hydroponic production of column stocks and this is currently being investigated further.

A number of growers have undertaken ’look-see trials‘ on the use of *Trichoderma* in column stocks during 2011, and while most of these trials were inconclusive, one nursery did see very promising results in the control of both *Pythium* and *Fusarium*. While these trials were not scientifically replicated, they did justify the further investigation of biological control agents such as *Trichoderma*. These grower trials were continued into 2012, and apart from one anecdotal account, there was no evidence of any improvement in either growth or disease control from the use of *Trichoderma*. However, a more extensive confidential trial using frequent applications of a range of biological agents has been reported to have been successful in 2013, but this was not in a soil that had a history of *Fusarium*; it is hoped that the results of this trial will soon be freely available.

The extensive, fully replicated trials undertaken in 2012 showed that the only treatments to have any effect on both growth and disease control were spent mushroom compost and composted bark used as a soil amendment. Composted bark was used extensively in commercial-scale grower trials in 2013 (HDC Project PO 005a). However, the beneficial results could not be repeated, in fact on one nursery the level of *Fusarium* increased substantially in the area that had been treated with bark, and at this stage the anomaly cannot be explained. A summary of these trials is included as Appendix 1.

Conclusions

- Growers should (and in many cases already have) look at the findings of this work and apply the information to their own individual situation. A good example of this would be not to grow the Aida and Figaro families if the soil has not been steam-sterilised. Also, when growing later planted crops, if possible it would be wise to avoid planting Francesca, Centum Deep Blue and Opera Deborah in houses with a history of *Fusarium* wilt.
- Unfortunately this project has shown that none of the current chemical or biological solutions will enable growers to move away from regular steaming, especially in

glasshouses with a history of *Fusarium*. However the work has prompted some of the suppliers of biological agents to rethink the current strategy for use and to possibly develop alternative recommendations in the future.

- This work has served to bring the UK's column stock growers closely together and for them to mould clearly the nature of the R&D they want to see carried out.

Knowledge and Technology Transfer

- The key technology transfer activity was the regular grower walks that occurred throughout the season. The grower walks, while not part of the original proposal, have proved very popular and the participating growers have gained a great deal from this so far unprecedented level of cooperation. This has in fact led some growers to comment that this is the best HDC project that has ever been funded within their sector.
- Three articles appeared in *HDC News*, in June 2011, November 2012 and May 2013.
- Presentations summarising the work were given to the South Holland Growers Club on 6 February 2012 and 21 January 2013.
- Presentations were also given at the CFC Open Days in September 2012 and August 2013.

In addition to the grower walks, the grower trips to Holland and Northern Ireland were of great benefit to the growers and served to bring the producers, propagators and breeders closed to together in a spirit of cooperation rather than antagonism. The Irish trip was partially funded by the GCRI Trust and a report of the visit is included (Appendix 2). The following points are observations made during the Dutch trip:

- Dutch growers are totally reliant on steaming, which is considered to be a standard prerequisite to growing the crop.
- AYR production of column stocks tends to give a product that is inferior to the strong, sturdy UK naturally grown column stocks; stocks do not lend themselves to being 'forced'.
- Some Dutch grower's produce column stocks in a similar way to UK growers, and the resulting product was comparable to a UK column stock.
- *Fusarium* is not such an issue in Holland, probably as a result of the extensive use of steam, but it was still present especially along the sides of the central concrete pathways.
- Again, owing to the extensive use of steam, Dutch growers do not tend to see the issues of poor growth of Aida and Figaro that we see in the UK.

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Appendix 1: 2013 bark incorporation trials (PO 005a)

Introduction

The HDC-funded trial PO 005, described in this report, demonstrated in 2012 that none of commercially available fungicides or bio-pesticides gave adequate control of *Fusarium* in column stocks. However, the soil incorporation of composted, mixed conifer bark showed both a significant reduction of *Fusarium* in infected soil, as well as improvements in overall stem quality (increasing the number of marketable stems) in steamed soil with low *Fusarium* pressure (Figure A1). The very positive results from these trials encouraged a number of growers to undertake commercial scale trials of bark incorporation in 2013.

Figure A1. Plots from the 2012 glasshouse *Fusarium* trial in steamed soil, showing severe *Fusarium* infection (left) and healthy plants in bark-treated soil (right)

2013 grower trials

The bark used in the trials was all mixed conifer from Melcourt and was either delivered in bulk or as bales. It was applied at 30L/m^2, which is referred to as full-rate in the following report. Where possible these trials were designed for easy comparison with control plots, and to look at as many treatments as practical. The factors investigated were:

- Full-rate bark incorporation versus no bark in first-round crop
- Full-rate bark incorporated with the first- and second-round crops
- Full-rate bark incorporated with first-round crop but none with the second round
- Full-rate bark incorporated with -first-round crop and half-rate with -second-round crop pre steaming

- Full-rate bark incorporated with the first-round crop and half-rate with second-round crop post-steaming
- The use of bark in glasshouses and tunnels
- Interactions with ’green waste‘ incorporation and sterilisation by Basamid.

Further details of the trial sites are as follows.

Site 1 (Hillgate glasshouse)

Two sides of a glasshouse were used for the trial, with one bay each side having been treated with full-rate bark and an adjacent bay having no bark added. The total area of the glasshouse was 3,200m^2, with 18 half-bays, with each half bay being 26 x 6.4m. Figaro Light Rose was planted in one bay of the trial (i.e. on adjacent bays with either bark or no bark), and Figaro Lavender and Fedora Deep Rose were planted in the other bay (i.e. either bark or no bark on adjacent rows).

Site 2 (Belmont glasshouse)

The trial was conducted on one side of a glasshouse with one bay treated with full-rate bark and an untreated adjacent bay. Aida White and Figaro Lavender were planted in both of the trial bays. The total area of the glasshouse was 1,340m^2 comprising of 10 half bays each measuring 21.6 x 6.2 m with 6 stanchions.

Site 3 (Belmont tunnel)

Three bays on each side of the path were used for the trial, with half being treated with full-rate bark and half having no bark applied. The varieties grown were Figaro Lavender, Figaro Light Rose and Fedora Deep Rose, with a bay of each planted in both the bark and no bark treatment. The total area of the poly tunnel was 2,200m^2 comprising of 14 half bays each measuring 19.5 x 7.9 m with 9 stanchions.

Site 4 (Tuxhill new glass)

This was the most extensive of the trials and was undertaken in a modern glasshouse. The total area of the glasshouse was 5,500m^2, with 30 half-bays, each bay being 28 x 6.4m in area and producing two rounds of crops. The entire glasshouse was treated with full-rate bark prior to planting the first round, except for one bay. Six bays were used for the trial on the second-round crop, including the bay that was untreated before the planting of the first round. Each bay was planted with Figaro Light Rose, Figaro Lavender, Aida Blue and Fedora Deep Rose. The details of each treatment were as follows:

- Treatment 1 – Full-rate bark prior to round 1, additional full-rate bark prior to round 2
- Treatment 2 – Full-rate bark prior to round 1, no additional bark prior to round 2
- Treatment 3 – No bark prior to round 1 or round 2

- Treatment 4 – Full-rate bark prior to round 1, full-rate post-sheet-steaming for about 8 hours prior to round 2
- Treatment 5 - Full-rate bark prior to round 1, half-rate post-steaming prior to round 2
- Treatment 6 – Full-rate bark prior to round 1, half-rate pre-steaming prior to round 2

Site 5 (Tuxhill tunnel)

This trial was undertaken on a first round crop in a Spanish tunnel which had a history of high levels of *Fusarium*. Part of the tunnel was sterilised with full rate Basamid over the winter of 2012/13 and then the whole tunnel was steamed pre planting in the spring of 2013. The purpose of this trial was to compare the incorporation of green waste and bark and its interaction with sterilisation technique. The green waste was sourced from Donarbon and was applied at 28 l/m^2. Details of each treatment were as follows:

- Treatment 1 – Basamid sterilisation with full-rate bark applied pre-steaming (see protocol above)
- Treatment 2 – Basamid sterilisation with full-rate bark applied post-steaming
- Treatment 3 – Basamid sterilised with no further additives
- Treatment 4 – No Basamid and full-rate bark applied pre-steaming
- Treatment 5 – No Basamid and full-rate bark applied post-steaming
- Treatment 6 – No Basamid and no other additives
- Treatment 7 – Basamid sterilised and green waste added pre-steaming
- Treatment 8 – Basamid sterilised and green waste added post-steaming

Site 6 (Drainside old glasshouse)

This trial was undertaken in an old glasshouse with one bay treated with full-rate bark and the other with non-sterilised soil. The glasshouse has a history of column stock production and was steamed in 2012. Each bay was planted with Centum White.

Site 7 (Lambs Flowers old glasshouse)

Trials were undertaken in four older glasshouses, of which only one had a slight history of *Fusarium*. The trial looked at the use of two different sources of bark, the standard mixed conifer bark as used on all the other sites, and a pine bark. Standard rates of bark were used in all of the trial bays.

Three of the glasshouses were 2,000m^2 and the fourth was 1,350m^2. In each house, 1 bay was left untreated i.e. no bark was added. Each glasshouse was planted with Centum white, Centum yellow, Fedora deep rose, Figaro Lavender, Figaro rose light, Opera Deborah and Opera Francesca.

Results

Despite the encouraging trials in 2012, in the large-scale commercial trials in 2013 the addition of bark did not reduce *Fusarium* infection and had no positive impact on the quality of stems produced. In fact, one nursery actually saw a significant amount of *Fusarium* in the area treated with bark, but virtually none in the control area. At this stage it is not possible to explain this result, but it seems possible that the bark addition contributed to the development of a favourable environment in which *Fusarium* could spread, though this is contrary to previous observations.

In 2013 some crops suffered very severe *Fusarium* infection in late crops, despite the soil being sterilised and bark being incorporated at the standard rate. This could have been influenced by the very high temperatures during July, which would have favoured *Fusarium* infection. However, since cooler weather earlier in the season would not have been conducive to *Fusarium* infection, weather alone cannot explain why the positive results in the 2012 trial was not repeated in the 2013 commercial-scale trials. Figure A2 shows that a similar level of *Fusarium* infection was seen in both bark-treated and non-treated areas.

Figure A2. The same glasshouse with areas treated with bark incorporation (left) and without bark incorporation (right), 2013 grower trial

All assessments were undertaken after all the marketable stems had been harvested. The numbers of stems with obvious *Fusarium* and of poor quality unmarketable stems were counted, and the results are shown below. The *Fusarium* count was based on observed symptoms rather that confirmed infections, which obviously would have been impractical to undertake. Because of the general interest by growers of column stocks in the proportion of stems bearing single flowers, this was also recorded although it would not have been affected by the addition of bark.

Site 1 (Hillgate glasshouse)

A full bay was recorded, i.e. Figaro Light Rose and a mixture of Figaro Lavender and Fedora Deep Rose with and without bark (Table A1). Although less than 1% of plants were affected by *Fusarium*, contrary to expectations there appeared to be more *Fusarium* in beds where bark had been applied. Other poor quality stems accounted for nearly 2% of stems in Figaro Light Rose and just over 3% of stems in Figaro Lavender and Fedora Deep Rose, but there was no effect of bark treatment on this proportion.

Table A1. Numbers of stems with *Fusarium*, damaged or otherwise poor quality stems, and single-flowered stems, in plain soil or soil amended with bark at Site 1. Based on 10,000 plants of each of the two varieties (or variety mixtures) shown, assessed on 22 June 2013.

Category of stem	Figaro Light Rose				Figaro Lavender & Fedora Deep Rose			
	No bark		Bark applied		No bark		Bark applied	
	Number	%	Number	%	Number	%	Number	%
Fusarium	45	0.4	86	0.9	17	0.2	52	0.5
Poor quality	186	1.9	175	1.7	335	3.3	327	3.3
Singles	33	0.3	21	0.2	39	0.4	21	0.2

Site 2 (Belmont glasshouse)

There was an obvious edge effect in this glasshouse, especially along the path, which had more *Fusarium* than most of the planted area, and in order to take account of this the assessments were undertaken between stanchions 2 to 5.(i.e. half of a bay). The proportion of plants affected by *Fusarium* was 2% in non-amended soil but twice this where bark had been applied (Table A2).

Table A2. Numbers of stems with *Fusarium*, damaged or otherwise poor quality stems, and single-flowered stems, in plain soil or soil amended with bark at Site 2. Based on 5,142 plants, assessed on 19 July 2013.

Category of stem	Aida White & Figaro Lavender			
	No bark		Bark applied	
	Number	%	Number	%
Fusarium	105	2.0	185	3.6
Poor quality	83	1.6	72	1.4
Singles	10	0.2	12	0.2

Site 3 (Belmont tunnel)

This assessment was undertaken between stanchions 4 to 6 in (i.e. a fifth of a bay) each of the six trial bays. Generally the proportion of plants affected by *Fusarium* was less than 1%, but this increased to 4.3% in Figaro Light Rose that had received the bark amendment (Table A3).

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Table A3. Numbers of stems with *Fusarium*, damaged or otherwise poor quality stems, and single-flowered stems, in plain soil or soil amended with bark at Site 3. Based on 2,464 plants of each of the two varieties, assessed on 19 July 2013.

Category of stem	Figaro Lavender				Figaro Light Rose			
	No bark		Bark applied		No bark		Bark applied	
	Number	%	Number	%	Number	%	Number	%
Fusarium	11	0.4	21	0.9	16	0.6	106	4.3
Poor quality	20	0.8	35	1.4	47	1.9	15	0.6
Singles	6	0.2	4	0.2	5	0.2	7	0.3

Site 4 (Tuxhill glasshouse)

The assessments in this area were undertaken between stanchion 5 to 6 (i.e. a sixth of each bay) in each of the six trial bays. There were six treatments, all involving a mix of four varieties. From the results (Table A4) it may appear as if the double-bark treatment (treatment 1) increased the level of *Fusarium*. However the two commercial bays directly adjacent to the trial bay also had severe *Fusarium*, so it is likely that this is an artefact related to this area of the glasshouse rather than a treatment effect.

Table A4. Numbers of stems with *Fusarium*, damaged or otherwise poor quality stems, and single-flowered stems, in six soil amendment treatments involving bark at Site 4. Based on 1,833 plants in each treatment, assessed on 20 July 2013.

Round 1 tmt	*Full rate bark*		*Full rate bark*		*No bark*		*Full rate bark*		*Full rate bark*		*Full rate bark*	
Round 2 tmt	*Full rate bark*		*No bark*		*No bark*		*Full rate bark post steam*		*Half rate bark post steam*		*Half rate bark pre-steam*	
Category of stem:	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Fusarium	290	15.8	5	0.3	2	0.1	82	4.5	90	4.9	43	2.3
Poor-quality	215	11.7	75	4.1	52	2.8	21	1.1	23	1.3	15	0.8
Singles	16	0.9	16	0.9	5	0.3	7	0.4	8	0.4	6	0.3

Assessments at site 5 (Tuxhill tunnel)

A visual inspection on the 14 July 2013 indicated that there was no obvious visual difference between any of the treatments, and very low levels of *Fusarium* in the trial area. Unfortunately the beds were cleared before final counts of unmarketable stems had been carried out.

Assessments at site 6 (Drainside glasshouse)

The assessment in this area was undertaken between stanchions 4 to 7 in each of the trial bays. The proportion of stems affected by *Fusarium* was much greater in soil amended with bark (13.5%) than in the non-amended soil (1.6%) (Table A5).

Table A5. Numbers of stems with *Fusarium*, damaged or otherwise poor quality stems, and single-flowered stems, in plain soil or soil amended with bark at Site 6. Based on 2,520 plants, assessed on 6 August 2013.

Category of stem	**Centum White**			
	No bark		**Bark applied**	
	Number	**%**	**Number**	**%**
Fusarium	39	1.6	340	13.5
Poor quality	175	6.9	28	1.1
Singles	16	0.6	21	0.8

Assessments at site 7 (Lambs Flowers glasshouse)

These assessments were undertaken by the grower and they are shown as percentages of stems cropped in the overall glasshouse. While there is no separate figure for treated and untreated areas, in these houses, virtually all of the losses occurred in the areas treated with bark, with negligible or no *Fusarium* in the non treated control bays. There was no obvious visual difference in the *Fusarium* levels between the 2 sources of bark.

Glasshouse number	**Total planted**	**Total Cropped**	**% infected with *Fusarium***
One	86,000	67,900	21%
Two	132,000	99,000	25%
Three	132,000	102,000	23%
Four	132,000	77,000	41%

Discussion

In most of the trial houses there was no obvious visual difference in the marketable yield or levels of *Fusarium* between the untreated areas and those treated with bark. This was also true of the trials looking at the full and half rate bark applications and its incorporation either pre or post steaming. These observations were confirmed by the counts of the non-cropped stems in trial areas as shown in results above. If the trial area corresponded with an area of high *Fusarium* pressure, then the levels of losses were equally high in the untreated area and the treated area, and *vice versa* for areas with low disease pressure.

The results observed in the 2013 trials are disappointing and perhaps a little surprising in the light of the substantial improvements in both yield and the reduction of *Fusarium* incidence observed in the trial plots in 2012. The reasons for the failure of the 2013 trials to show an improvement cannot be explained using the data collected from these observational trials, but various theories have been put forward, including the possibility that the microflora of the 2012 bark supply was exactly right to improve crop growth, differences in nutrient status or balance of the soil between 2012 and 2013, and differences in soil temperature. None of these fully explains the results but it would need much more detailed and costly trials to separate one variable from another.

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Of greatest concern from the 2013 trial was the severe increase in the levels of *Fusarium* at site 7 in the areas treated with both composted and pine bark compared with the untreated controls. This was in glasshouses with no previous history of high levels of *Fusarium*, but from observations by the author and others there was no doubt that the bark-treated areas had substantial levels of *Fusarium* with either no or only a trace amount being present in the untreated control. This data does not suggest that the bark introduced *Fusarium* into the soil, but it may have contributed to an environment which enabled *Fusarium* to thrive and multiply. The reasons for these observations cannot be fully explained at present.

Growers participating in the trials agreed that soil structure was greatly improved by the addition of composted bark, which made planting much easier and appeared to enhance establishment of the seedlings. But without the anticipated improvement in marketable stems the cost of bark (i.e. £25/m^3) is likely to be prohibitive. Growers are therefore looking for affordable alternatives to improve soil structure, and have considered amendments such as mushroom compost or green waste. However a number of these alternatives have inherent risks such as high EC or potential herbicide contamination and growers are advised to investigate the implications of any organic soil amendments fully prior to taking action.

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Appendix 2: Report of a study tour on Irish column stock production and trials

The award of a GCRI Trust travel grant enabled the author to facilitate and participate in a study tour to Northern Ireland on 2 – 3 August 2011 to allow mainland column stock growers to compare and benchmark NI production with particular reference to soil-borne disease issues. A visit to Greenmount College research facilities was included as part of the study tour. This is a copy of the final report submitted to the GCRI Trust. The findings of the study tour helped to shape the second year of the HDC-funded project PO 005 (an investigation into the cause(s) of poor establishment, growth and flower uniformity of column stocks).

The businesses participating in the study tour were J A Collison and Sons, Lambs Flowers Ltd, Whiteheads of Boston, Belmount Nurseries and Geaters of Lieston, collectively representing about 80% of the British columns stock production area. The nurseries visited in Northern Ireland were Derryland Nurseries Ltd, Plunketts Nursery and Thomas Morrow & Sons, as well as the Department of Agriculture & Rural Development Northern Ireland's (DARDNI) Greenmount Campus.

The study tour demonstrated that even though the NI column stocks industry is not as well established as the British industry, the same issues are becoming troublesome. This is particularly true of *Fusarium* wilt which is firmly established as a serious disease problem on the nurseries that have been producing column stocks for some years. As in the UK, *Fusarium* is only partially controlled by steam sterilisation and Centum Deep Blue is a variety particularly badly affected by the disease, especially in the 2011 season. There was also agreement amongst British and NI growers that the evenness of the crop had deteriorated in recent years, an issue discussed in depth with both the propagator and breeder during a trip to Holland earlier in the year.

The study group participants looking at the column stock crops at Derryland Nurseries

The NI growers have undertaken a few trials using *Trichoderma,* in the form of Kopperts Trianum, a seedling and soil drench, to determine if it is beneficial in the control of

Fusarium. Unfortunately, owing to the nature of the trials (in some cases no control was included) these trials proved inconclusive. However, some of the growers felt that *Trichoderma* did show a positive effect on growth and root establishment and it is hoped that further trials will be undertaken.

The visit to Greenmount was very informative and looked at a wide range of horticultural trials including lily variety trials, alternative growing media and biomass heating systems. Of particular interest to our group of growers were the trials involving column stocks. These included comparison of varieties from Florensis and van Klink and the effect on evenness of flowering of the mechanical gapping up procedure at the Dutch propagation stage. The college has also looked at the production of flowers in hydroponics systems. However, this was not successful for column stocks, so it will be redesigned and looked at again next year. All of the growers were very impressed with the variety and quality of the work being undertaken at Greenmount.

On behalf of myself and all of the study group participants, I would like to thank the GCRI Trust and the HDC for providing the funding to enable this study tour to take place.

The study tour participants viewing the trials at Greenmount campus

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Appendix 3: Steam sterilisation – a summary of current practice

Since the start of this project in 2011, most column stock growers now sterilise their soil using steam. In 2012 this figure was about 95%, with the remaining 5% being either non-sterilised or treated with Basamid (or Dazomet). Of the 95% of steam-sterilised area, in 2012 about 59% was treated using 'dry' steam and 36% using 'wet' steam. Almost all of the current steam sterilisation uses sheet steaming with an additional thermal blanket covering the steam sheet to reduce both energy use and cook time. For other crops such as lisianthus, one grower is using vacuum steaming, i.e. the use of permanent porous pipes buried at about 60cm which are connected to a small pump in order to produce a vacuum within the soil hence drawing the steam down into the vacuum. The advantage of this technique is that it produces more thorough steaming to depth and more effective heating resulting in a shorter steaming period, more efficient kill of pathogens and less fuel use.

Dry steam

Dry or superheated steam is produced by a technique that heats the steam twice to produce very hot but dry steam which comes out of the boiler at in excess of 200°C (one grower has measured 230°C coming out of the boiler, with a temperature of 140 to 200°C at the point of delivery to the sheet, dependent on distance from the boiler). This is usually produced by mobile boilers (e.g. those made by Moeschle - http://www.moeschle.de/index.php?lang=en) that burn light oil and can be moved from one glasshouse to another. Dry steam boilers run at low pressure and are not subject to annual inspections and certification.

Wet steam

Wet steam boilers are either an integral part of the nursery infrastructure, also heating the glasshouses, or they may be hired from usually a Dutch company. These are usually very large boilers which are delivered on a lorry and will sterilise the nursery from a central location. These boilers produce 'traditional' steam, heated to about 108°C, and operate at a much higher pressure than mobile dry steam boilers. As a general rule the glasshouse soil needs to be drier than when sterilising with superheated steam, because of the initial higher moisture content.

Soil preparation

Most growers currently prepare the soil for sterilisation by the use of a spader which will result in a rough tilth which helps the steam to penetrate as deeply as possible. However, the soil may require further cultivations if the size of clods exceed roughly the size of a fist, otherwise these would be too large for the steam to penetrate.

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Soil moisture status is also important because too wet a soil will not allow the steam to penetrate adequately, and too dry a soil (especially when using superheated steam) can result in a poor kill of pathogens. It is impossible to be prescriptive over this issue, but most growers know their own soils and are able to judge the correct moisture status whenever it is practically possible (it is obviously easier to wet-up a dry soil than it is to dry-out a wet soil).

Steaming duration

Most growers tend to sheet-steam for about 7 to 8 hours, but could steam for longer depending on the soil type or perception of disease risk of the soil being sterilised. A small number of growers would steam for less than 7 hours, but this tends to be the exception rather than the norm. Most growers do not rely on probes to measure the temperature and depth of the steam penetration because they do not feel that they are reliable. It is felt that the readings vary considerably dependent on where they are placed within the area being steamed. It is for this reason that most growers rely on time to determine the efficacy of the steaming process.

Planting time

There is no fixed period of time that growers leave the soil after steaming before planting the crop. Some growers have a steaming regime that means the soil will only be left for a few days before the area is planted. Other growers, especially those who are hiring Dutch boilers, would tend to steam the whole nursery in late-autumn or early-winter, and planting may not then take place for 2 or 3 months. From the observations made over the past few years there is no obvious difference in either crop quality or disease control from the different periods that the soil is left before the crop is planted.

Cost of steaming

The amount of oil used to sterilise a glasshouse obviously varies with the type of boiler, soil type and duration of the steaming. However, the average use of fuel seems to be about 2.5 to 4L/m^2 for growers that keep the necessary record to enable this to be calculated. When fuel and labour (and hire of boiler if applicable) are taken into account, the cost of steam sterilisation varies from £2.00 to £4.00/m^2.

Thermal death points

Work undertaken by ADAS (see HDC Factsheet 09/07, Soil disinfestations options for cut flower growers) showed that the heat input required to kill pathogens is a function of temperature and time. A temperature of 65°C in moist soil is usually sufficient to kill most pathogens and pests, but unfortunately *Fusarium* requires a higher temperature of about

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80°C for 30 minutes (see report on HDC-funded project PC 213, Protected column stock: aspects of the biology and control of *Fusarium* wilt, a new disease problem), or 90 to 100°C if the fungus is protected by woody stem bases or roots.

Summary of the 2011 to 2013 survey work

Steaming is still a vital tool in the production of intensive UK flowers crops, especially column stocks, but it is a very expensive technique and cannot be considered to be very environmentally friendly owing to its high use of energy.

However, observations over the past 3 years have shown that many growers cannot reliably produce a good quality crop of column stocks without steaming mainly because of disease pressure from *Fusarium*, and because varieties such as Aida and Figaro will not grow in non-steamed soil. The technique is not entirely reliable and some crops still experience severe losses, especially due to *Fusarium* and even when the crop has been steamed. In some cases this can be explained, e.g. the soil was too wet when steamed, but in many cases there is no simple explanation for the lack of disease control. It is not uncommon to find areas of a crop within the same glasshouse with severe *Fusarium*, and others with very little *Fusarium* even though the whole house has been treated in the same way as regards cultivation, steaming, varieties planted and other cultural techniques. However, the houses which show consistent problems are usually - but not exclusively - those with a history of *Fusarium* going back many years.

Some growers are convinced that wet steam is more efficacious than dry steam, but this is difficult to confirm from the observations of the survey work. There is no doubt that the main two nurseries using wet steam had less *Fusarium* than those using dry steam, but both of these nurseries implement hygiene standards that are much higher than the industry norm, and neither has a history of *Fusarium* in their glasshouses. The nurseries with the worse cases of *Fusarium* are using dry steam, but they also have a history of *Fusarium* in the troublesome houses. Conversely there are nurseries using dry steam that do not have a history of *Fusarium* that have had very few problems with the disease over the period of the survey. Clearly this issue of dry versus wet steam requires further investigation.

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