HNS 125

Hardy ornamentals: The potential of compost teas for improving crop health and growth

Final Report 2006

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

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GROWER SUMMARY

HNS 125

Hardy ornamentals: The potential of compost teas for improving crop health and growth

Headline

Compost teas have the potential to improve crop growth and health in container-grown ornamentals including lavender, choisya, cordyline and phygelius. However, the effects of compost teas on plant growth and health are extremely variable. Compost teas had little or no effect on lavender or choisya plants grown in the first four trials in North East Scotland, or on rose plants in the trial in South East England. The greatest improvements in plant growth (in comparison with plants treated with plain water or standard fungicide programmes) were recorded in trials on commercial nurseries in the South of England. Considerable further work is required to find out how compost teas work and to develop methods for ensuring their efficacy in improving crop growth and health.

Project background

Growers of ornamental crops have access to a limited (and decreasing) number of effective fungicides and there is a continuing need to seek new ways of improving crop growth and health. Compost teas have been used for several years in the United States to stimulate healthy crop growth and to reduce the incidence and severity of disease. Around 70 UK growers are also currently experimenting with compost teas. There has been limited scientific work published to prove the effectiveness of compost teas and the recommendations being supplied to growers relating to their use is rarely based on scientific evidence.

<u>Compost teas defined</u>

Compost teas can be defined as the product of showering or circulating water through compost (or a porous bag of compost suspended over or within an open tank) with the intention of maintaining aerobic conditions. Most compost teas made in the UK and USA are now aerated during their production. They are therefore known as aerated compost teas. However, most of the published scientific work which has examined compost teas has looked at non-aerated compost teas.

<u>How to make compost teas</u>

In order to make compost teas, a grower requires a watertight vessel, compost and water. Nutrients may also be added prior to or following production, and additives can be added prior to application. Compost teas are generally made by mixing one volume of compost with between four to twenty volumes of water in an open or closed container. The mixture is stirred as it is made up, then it is left for between 12 hours and 3 days. During this period, aerated compost teas are stirred or aerated in different ways, depending on the type of brewer.

What can compost teas do?

Prior to this project, experimental work largely carried out in the USA showed that compost teas can, in some cases, improve plant growth and can help prevent and/or control a wide range of foliar diseases in glasshouse and field grown edible and ornamental crops. Examples of diseases controlled in this way include botrytis, leaf spots, root rots, mildews, rusts and scabs. It is important to note that control was not achieved with all pathogens in all tests. The degree of disease control varied a great deal.

How do compost teas work?

The effects of compost teas depend on the live microorganisms within them. In other words, if compost teas are heat-sterilised, they tend to have little or no effect. The live microorganisms within compost teas act as biological control agents.

There is an urgent need for independent scientific work to:

- optimise production methods and application strategies for compost teas
- assess the safety and minimise the risks to human health from the use of compost teas
- determine factors affecting efficacy of compost teas in order to improve efficacy

If successful strategies for the production and use of compost teas are developed, there is potential to reduce fungicide costs, to maintain or improve crop growth and health and to improve soil health in field grown crops.

Project aim and objectives

Overall project aim

To answer key questions relating to the preparation, application and effects of compost teas on UK ornamental nurseries and to give growers practical information to enable them to use compost teas to best effect following basic scientific work and glasshouse/tunnel trials.

The specific objectives were to:

1. Test the effect *(on crop growth, health and presence/absence of disease*) of teas made using four reputable compost tea brewers (Plates 1 to 4**)** available on the world market on two ornamental species under experimental glasshouse conditions.

2. Determine the effect *(on crop growth, health and presence/absence of disease*) of compost type on the quality and effects of the finished tea on two ornamental species under experimental glasshouse conditions.

3. Determine the effect *(on crop growth, health and presence/absence of disease*) of compost maturity on the quality and effects of the finished tea on two ornamental species under experimental glasshouse conditions

4a. Determine the effect of pre-brewing additives on compost tea performance
4b. Determine the effect of post-brewing additives on compost tea performance

5. Assess the characteristics (*pH, nutrient content, presence of beneficial organisms*) of compost teas used in trials carried out under Objectives 3 and 4.

6. Determine the effect *(on crop growth, health, biological control agents and presence/absence of disease*) of compost teas made using van Iersel compost and the Xtractor brewer on commercial nurseries.

7. Prepare a report based on work carried out in this study and an assessment of other important scientific work in the USA and Europe.

Main conclusions from project

Trial 1 - Effect of teas made using four brewers on ornamental crops

- None of the compost teas used had any effect on the growth of lavenders or choisyas (plant height or shoot dry weight), disease (*Botrytis cinerea*) or pest damage (two-spotted spider mite) when compared with plants treated with fungicides or plain water.
- The type of brewer used therefore had no effect on the quality of lavender or choisya plants or their susceptibility to pests or diseases.
- Details of the brewers used are shown below.

Brewer	**Manufacturer and address**
Xtractor (250 l)	Compara International BV. Available in the UK from Fargro Ltd., Toddington Lane, Littlehampton, Sussex, BN17 7PP
Earth Tea (22 gal)	EPM Inc., PO Box 1295, Cottage Grove Oregon 97424, USA
System 25 (25 gal)	Growing Solutions, 160 Madison Street, Eugene, Oregon 97402, USA
Compost Brewer (25 l)	Reading Compost Brewers Ltd., 42a High Street, Theale, Reading, Berkshire, RG7 5AN

- Shipping costs make both of the American brewers expensive. There was a problem with the pump on the Earth Tea brewer within a month of purchase, and parts proved difficult and costly to obtain. The Earth Tea Brewer also tended to produce a tea which was 2 to 5°C warmer than ambient, since the tea is used to cool the pump during production. This is undesirable, particularly during the warm summer months, when tea temperatures can easily become higher than the optima for many of the organisms within the brew. The American brewers were both more complex than the two UK models and were slightly more difficult to clean and maintain. Considering the cost, the difficulty of obtaining spare parts and the lack of evidence that they make better compost teas, there is no reason to suggest that UK growers should buy the American brewers.

- The Reading Compost Brewer performed well, was easy to clean and maintain and would be an excellent choice for growers wishing to try using compost teas on a small scale. Reading Compost Brewers have brought out a new, improved model since the one used in trials was obtained. They have also introduced a larger model.
- The Xtractor proved robust, reliable and is easily maintained. It seems very expensive for what it is, but it remains the only large compost tea brewer, which is easily available for UK growers to buy at present.

Trial 2 - Effect of compost type on the efficacy of compost tea

- There were rarely any differences in the growth (plant height or shoot dry weight), disease severity (*Botrytis cinerea*) or pest damage (two-spotted spider mite) on lavenders or choisyas treated with compost tea, fungicides or plain water.
- The effect of compost type used to make tea on the quality of lavender or choisya plants and on their susceptibility to pests or diseases was complex. Where treatment differences were observed between teas made from different composts, the poorest quality plants were usually those treated with tea made from van Iersel compost.

Trial 3 - Effect of compost age (maturity) on the efficacy of compost tea

- There were rarely any differences in observed parameters (plant height, number of flower spikes, shoot dry weight, amount of disease/pest damage), on lavenders or choisyas treated with the four types of compost tea, fungicides or plain water.
- The effect of the age of compost used to make tea, on the quality of lavender or choisya plants and on their susceptibility to pests or diseases was complex. Where treatment differences were observed, the treatment in which the best quality plants were found differed depending on the quality parameter (e.g. plant height, quality) being measured.

Trial 4a - Effect of pre-brewing additives on compost tea performance

- There was insufficient evidence to show that differences in pre-brewing additives had any effect on the performance of compost teas.

Trial 4b - Effect of post-brewing additives on compost tea performance

- There was insufficient evidence to show that post-brewing additives had any effect on the performance of compost teas on lavender.
- Choisya plants treated with compost tea without brewing additives tended to be lighter, shorter and more compact (and therefore of higher quality).

Objective 5 - Assessment of the characteristics of compost teas used in trials

- Plate counts showed that the numbers of total culturable bacteria recorded from brews in Trials 1 to 6 were generally within the range reported for disease suppressive compost teas (i.e. they were between 10^7 to 10^{10} colony forming units (CFU) per ml. There was no evidence of *Salmonella* species and there were very low numbers of *Escherichia coli* in the compost teas used in this work.
- Compost teas used had pH values of 7.1 to 7.4, eC values of between 459 and 1650 µS/cm and contained a good supply of macronutrients (P, S, K, Ca and Mg) and micronutrients (Fe, Cu B and Zn). The supply of each of these elements either singly or in combination (synergistic effects) could play a role in the beneficial effects of compost teas on plant growth and development including disease resistance.
- The composts used in this work were all of high quality. They would all have passed the criteria required to conform with the British Standards Institution Publicly Available Specification 100:2005 (PAS 100:2005) for composts. The pH values, salt concentrations, physical parameters and C:N ratios obtained were acceptable for composted products. Concentrations of plant available nutrients were appropriate for greenwaste composts and all of the composts were considered sufficiently stable according to PAS 100:2005.

Trial 6 Nursery-based trials to compare the performance of compost tea with plain water and standard fungicide programmes

- Seven trials were carried out at four Nurseries during 2004/05 on five plant species. Each nursery hosted trials on one or two species.

- **Lavender plants** grown at both West End Nurseries and Aline Fairweather and treated with compost tea tended to be significantly taller and have greater root and quality scores than those treated with plain water (and in some cases fungicides).
- There were no diseases in the lavender plants in either trial and no significant difference in the amount of pest damage between treatments.

- **Choisya plants** at Hewton Nurseries that were treated with compost tea were significantly shorter than those in other treatments at the final assessment, but not any bushier (i.e. they did not have more breaks) than those treated with plain water (control) or the standard fungicide programme at the final assessment.
- Choisyas treated with compost tea or fungicide had significantly greater quality scores than plants treated with plain water at the first assessment in December. Quality of plants treated with compost tea or fungicide then deteriorated during the trial period. At the final assessment, plants treated with compost tea had significantly poorer root and quality scores than control plants. The deterioration in quality scores may have been due to the presence of excess water in the pots.
- There were no diseases present in the choisyas. There was a moderate level of pest damage throughout the trial, but no significant differences in the amount of pest damage

between treatments. Plants treated with compost tea had significantly more weeds than those treated with plain water (control) or fungicide.

- **Phygelius plants** treated with compost tea or plain water were significantly taller than those treated with fungicide. Those treated with compost tea had a significantly greater number of breaks and significantly higher root and quality scores than those treated with plain water or fungicide.
- There were no diseases or weeds recorded during the trial period. There was a low level of pest damage throughout the trial, but no significant difference in incidence of damage between treatments.

- **Cordyline plants** at both Hewton and West End Nurseries treated with compost tea (and in some cases fungicide) were significantly taller and had significantly greater root and quality scores than those treated with plain water at the final assessment.
- The quality of plants treated with compost tea or fungicides in some cases deteriorated in comparison to the controls during the winter months, but application of compost tea was associated with improved plant growth in the spring in comparison to the conventional fungicide application.
- There were no diseases on the cordylines at West End Nurseries and low levels of disease at Hewton. There were no weeds in the trial at Hewton and low numbers of weeds at West End. However there were no significant differences in incidence of diseases or weeds between treatments.
- There was a low to moderate levels of pest damage throughout the trial at Hewton and plants treated with compost tea or fungicide had significantly fewer incidences of pest damage than the control treatment. There was a moderate level of pest damage throughout the cordylines at West End Nurseries, but no significant difference in incidence of damage between treatments.

- ***Rosa* 'Oxfordshire' plants** at Notcutts treated with compost teas were no better (in terms of plant height, number of shoots, disease incidence/severity, or the number of dead plants per plot) than untreated and fungicide treated plants.
- Compost teas did not affect the severity of spider mite infestation on roses, or have an adverse effect on *Phytoseiulus*, nor did compost teas seem to adversely affect aphid parasitism on roses, by either released or naturally occurring parasitoids.
- It was not possible to assess the effect of compost teas on the severity of aphid or western flower thrips infestations on roses.

Overall conclusions and future work

- Lavender and choisya plants treated with compost teas in Trials 1 to 4b were rarely better (in terms of plant height, quality or pest/disease incidence) than those treated with plain water or fungicides.

- Lavender, choisya, cordyline and phygelius plants treated with compost teas in the nursery trials (Trial 6) were frequently better (in terms of plant height, plant quality and root score) than those treated with plain water, and in some cases fungicides.
- Lavender, choisya, cordyline and phygelius plants treated with compost teas in the nursery trials (Trial 6) rarely had less damage due to pests, diseases or weeds than those treated with plain water or fungicides.
- Roses treated with compost teas in Trial 6 were no better (in terms of plant height, plant quality, root score or pest/disease incidence) than those treated with plain water or fungicides.
- Despite the fact that the use of compost teas was associated with improved plant growth and quality in several ornamental species in the nursery trials (Trial 6), the performance of compost teas across the entire project was extremely inconsistent. Compost teas often had no effect, although they rarely had deleterious effects.
- Considerable further work is required in order to develop a fuller understanding of how compost teas work, in order to develop reliable protocols for their use.
- Results from trials carried out in this project suggest that nursery-based trials, with multiple sampling points within large plots would be most likely to yield useful information. Plants from these multiple sampling points would be assessed for quality, incidence/severity of pest attack/diseases. Effects on biological control agents would also be better assessed in large plots.
- Numbers and activity of micro-organisms in compost teas and in growing media must be studied in more detail if they are to be understood with a view to optimising their effects in crop production.

Financial benefits

There are significant financial benefits to be gained through using compost teas (with limited use of fungicides where required) rather than a full, preventative fungicide programme.) It is difficult to generalise, because different growers use different quantities of fungicide, depending on the crops grown and the production system. However, savings of between 55% and 72 % are typically achieved when growers opt to use compost teas as part of their integrated crop protection programme (based on a reduction in both labour and fungicide costs). A more detailed appraisal of potential financial benefits is presented in Appendix IV.

Action points for growers

- By all means try compost teas on your nursery. There are now around 70 progressive UK growers using compost teas as part of their production system and there are many more in mainland Europe. Many of these growers are completely convinced of the benefits of compost teas in terms of their effects on plant quality, and some are saving a considerable amount of money due to reduced fungicide costs.

- Compost teas are best used as part of a total, or holistic approach to growing better quality plants with lower inputs. An essential part of this approach is staff involvement. Nurseries who are having success with compost teas have allowed their staff to experiment, refine and improve the compost tea system and tailor it to their own situation.
- Although compost teas have rarely been shown (in published work) to have deleterious effects, there is plenty of evidence in the literature to show that they can have no effects at all, or only have effects some of the time.
- Speak to UK growers currently using compost teas and find out how they are being used in practice before deciding on whether to try them on your nursery.
- Hold a forum on compost teas. Invite tea users/experts to share knowledge and ideas.
- Source compost tea kits from UK suppliers and use any type/age compost to prepare it although bear in mind results may be poorer if using van Irsel compost.

SCIENCE SECTION

GENERAL INTRODUCTION

There is evidence that sprays based on compost extracts have been used for hundreds of years. Their use declined when pesticides became available in the 20th century, since pesticides tend to give better, more reliable control of most foliar diseases. However, recent increases in sustainable and organic farming and problems relating to pesticide use have led to a significant resurgence in interest in compost extracts and teas. In relation to this project, growers of ornamental crops have access to a limited (and decreasing) number of effective fungicides. Some ornamental crops suffer phytotoxicity symptoms when certain fungicides are applied, particularly during the propagation or young plant stage. There is a continuing need to seek new solutions for improving crop growth and health. A great deal of work has been done to develop improved methods for preparation and use of compost extracts and teas. Most of this work has been done in the United States and much of it by commercial companies rather than federal research institutes. The work and the key findings from it are outlined here.

The term "compost tea" has not always been associated with an aerated fermentation process. It is important to distinguish between compost teas prepared using aerated and non-aerated processes, therefore the terms aerated compost tea (ACT) and non-aerated compost tea (NCT) will be used in this report to refer to the two dominant compost fermentation methods. ACT will refer to any method in which the water extract is actively aerated during the fermentation process. NCT will refer to methods where the water extract is not aerated or receives minimal aeration during fermentation apart from during the initial mixing.

<u>Production of compost teas</u>

The production of aerated and non-aerated compost teas both involve compost being fermented in water for a defined time period. Both methods require a fermentation vessel, compost, water, incubation and filtration prior to application. Nutrients may be added prior to or following fermentation and additives or adjuvants may be added prior to application. Compost teas are generally made by mixing one volume of compost with between four to twenty volumes of water in an open or closed container. The mixture is stirred as it is made up, then it is left for between 12 hours and 3 days. During this period, NCT's are given minimal or no stirring. ACT's are stirred or aerated in different ways, depending on the type of brewer. Compost teas can be made in quantities ranging from a few litres to several thousand litres in a single batch depending on the size of the fermentation vessel.

<u>Effect on plant disease</u>

Compost teas have been shown to help prevent and/or control a wide range of foliar diseases in glasshouse and field grown edible and ornamental crops. A comprehensive account of diseases which have been fully or partially controlled through the application of compost teas or extracts under experimental conditions is given in Scheuerell and Mahaffee (2002). Examples of diseases controlled in this way include those caused by *Alternaria* spp., *Botrytis cinerea, Phytophthora infestans, Plasmopara viticola, Sphaerotheca* spp., *Uncinula necator* and *Venturia inaequalis*. It is important to note that control has not been achieved with all pathogens in all tests. Efficacy varies depending on the crop and experimental system.

Most of the published evidence to demonstrate control of foliar disease concerns NCTs or compost extracts. At present, there is a shortage of data which compares the efficacy of ACTs and NCTs in controlling foliar diseases. A recent study by Scheuerell and Mahaffee (personal communication) examined the role of aeration and three different compost types on the efficacy of compost teas for controlling powdery mildew (*Sphaerotheca pannosa* var. rosae) on rose. All six compost teas significantly reduced powdery mildew in comparison to a control spray of water, but there was no difference in efficacy between ACTs and NCTs.

There are now several commercial companies in the United States, one in The Netherlands and one in the UK which are selling and promoting the use of machinery to make ACT's. However, there is little scientific evidence to demonstrate the efficacy of ACT's or to show that they are any more effective in controlling disease than NCTs. A limited number of the controlled studies carried out to date have been summarised in Scheuerell and Mahaffee (2002). Trials on a range of crops have shown that the effects of ACTs vary considerably. For example, no effect of ACT applications on early blight of tomato was observed; lettuce drop (several pathogens) was reduced in a summer but not a spring crop; post-harvest fruit rot of blueberries was significantly reduced, but this was offset by reduced yields.

Recent work by Scheuerell and Mahaffee (2004) examined the effects of ACTs and NCTs produced with and without pre-brewing additives on damping-off caused by pythium (*Pythium ultimum*) on cucumber. They found significant disease suppression on some occasions when NCTs (based on a range of compost types) were applied with a single additive. Additives included a bacterial nutrient solution (Soil Soup Inc., Edmonds WA, USA), Maxicrop soluble seaweed powder, humic acids or rock dust. However disease suppression was not observed in all five repeat bioassays. Similarly, they found significant disease suppression on a few occasions when ACTs (based on a range of compost types) were applied either without additives or with bacterial nutrient solution. Where disease suppression was found, it was not consistent over the five repeat bioassays. However, they found that when ACTs (based on a range of compost types) were applied with a single additive (seaweed powder, humic acids or rock dust) they suppressed *P. ultimum* damping-off in all 19 bioassays carried out.

In conclusion, the impact of ACTs on plant health and crop yield can be crop specific and often depends on the experimental system, environmental conditions and on the pre-brewing additives used. General statements about the efficacy of ACTs cannot be made, due to extreme inconsistency in the level of disease suppression reported.

Compost teas are also being widely advertised and used on both organic and conventional farms (mainly in the United States, but also in Europe) as an inoculant to restore or enhance soil microflora (Diver, 1998). However, very little work has been done to quantify the benefits from using compost teas in this way. There has been some work carried out to determine the effects of NCTs on seedborne pathogens through seed treatment. There has also been limited work done on soilborne pathogens *in vitro*, but it is well known that successful disease control *in vitro* does not always translate to field conditions. Recent work has shown that fusarium wilt of pepper (*F. oxysporum* f.sp. *vasinfectum*) and cucumber (*F. oxysporum* f.sp. *cucumerinum*) was controlled by drenching NCT on to soil under greenhouse conditions. The mode of action of the NCT was investigated *in vitro* and it had a mycolytic effect on fusarium microspores and chlamydospores, which showed that destruction of the pathogen propagules could be important in disease suppression

<u>Potential effect on soil/growing media health</u>

Soil health is central to any sustainable crop production system where reliance on synthetic fertilisers and pesticides is minimised, but it’s potential has not yet been fully explored. The health of a soil or growing medium has physical, chemical and biological components. The biological component of soil health depends on the numbers, diversity and health of the organisms including soil microflora present. Soil (and growing medium) health is associated with biological diversity and stability. It has been suggested that plant disease outbreaks can be regarded as indicators of instability and poor ecosystem health. It is therefore thought likely that there are links between soil (or growing medium) health, the ability of the biological community to suppress plant pathogens, populations of soil-borne plant pathogens and also disease incidence and severity.

Soil health monitoring is rarely practiced in Europe, but in some parts of the United States, farmers are using test kits to determine chemical, physical and biological components of soil health (e.g. Solvita, 2004). These have proved useful in demonstrating effects of management on soil health. Advice is widely given from several compost tea brewer manufacturers that compost tea drenches can improve the health of soils and growing media. However, at present, there is very little scientific evidence to demonstrate the impact which compost extracts or teas can have on soil health and the presence of beneficial microorganisms.

<u>Potential problems with compost extracts and teas</u>

At present, the main potential problem with compost teas (apart from reports of variable efficacy in controlling plant disease) appears to be the concern that fermenting compost could potentially support the growth of human pathogens. For example, faecal coliform and salmonella populations have been detected in the source compost, the NCT fermentation and on samples of field-grown broccoli and leeks sprayed with the NCT. Present evidence shows that pathogens can grow during the production of both ACTs and NCT's. However, the indications are that pathogen growth is not supported when ACTs or NCTs are prepared without fermentation nutrients. Further study of the potential for propagation of human pathogens is outside the scope of this project, although the intention is to monitor for the presence of fecal coliforms in the teas used in experimental work where time and resources permit.

Mode of action of compost teas

Compost teas sprayed on to plant leaves act on the leaf surface. The principal active agents in compost teas appear to be bacteria and fungi in the genera *Bacillus, Serratia, Penicillium* and *Trichoderma*, although other genera are involved. There is no single mechanism which explains the effects of compost extracts against foliar plant pathogens. It is possible to divide the effects of compost extracts into three categories:

- inhibition of spore germination
- antagonism and competition with pathogens
- induced resistance against pathogens

The main effects of compost extracts and teas appear to be associated with live microorganisms. Sterilised or micron filtered compost extracts have usually been shown to have significantly reduced activity against test pathogens. In a few cases, sterilised extracts have been shown to have limited activity against foliar pathogens. For example some chemicals produced by *Pseudomonas* spp. (e.g. siderophores) have been shown to exert a powerful chemical effect against other organisms. Antiobiotics have been shown to be produced by *Bacillus subtilis* and these inhibit the growth and germination of many fungal species.

The phenomenon of induced or acquired systemic resistance may also explain part of the mode of action of some compost extracts and teas. There is plenty of evidence to show that microorganisms (whether pathogenic or not) can induce plant defence responses. For example, when cucumber leaves are inoculated with the fungus *Colletotrichum lagenarium*, the infected leaves become resistant not only to attack by *C. lagenarium*, but also towards all other foliar pathogens. Knowledge of this phenomenon and its potential for control of plant pathogens is limited at this time.

Factors affecting efficacy of compost teas

There is sufficient information to show that in some cases, plant pathogen control has been at least as good with compost teas as with conventional fungicides. However, research also suggests that different preparation methods and different composts may be required in order to optimise the qualities of the final product and the application method.

A review of this subject is made in the report written for Defra by Litterick *et al.* (2003) for Objective 4 of Defra project OF0313 and a full list of references is given there. This report is available from Defra and can be accessed through their website (www.defra.gov.uk/farm/organic/default.htm).

Background and rationale for the project

Compost teas have been used in the USA as an alternative to fungicides on conventional and organic farms and nurseries for several years. They are being used to prevent and control foliar and soil-borne disease and to improve the health of soil and growing media. There are at least 15 companies making and selling compost tea brewers in the United States. Many of these brewers are aimed at gardeners and allotment holders, but some are made in larger sizes suitable for farmers and commercial horticulturists. The Compost Tea Industry Association (http://www.composttea.org), The Compost Tea Information and Research Foundation and the International Compost Tea Council (http://www.intlctc.org) have recently been formed in the United States. These organisations aim to provide unbiased information and aim to promote the safe, effective use of compost teas in farms and gardens.

Compost teas have been used on commercial horticultural holdings (on ornamentals) in The Netherlands for around 2 years. To our knowledge, all Dutch growers who use compost teas are buying kits including compost and compost tea brewers from van Iersel, a company which advocates a production system known as "Microfarming".

Following reports of successful use of compost teas on nurseries in The Netherlands, around 70 UK ornamental growers are in the early stages of experimenting with compost teas on their nurseries. They are interested in finding out whether compost teas can improve crop growth and/or health and whether they can help reduce reliance on fungicides.

Most of the recent work relating to compost teas in the United States and The Netherlands has been carried out by commercial companies who are selling proprietary compost tea brewers and/or kits to make compost teas. Some of the advice which has been given to growers (particularly in the United States) has been inappropriate and based on few scientific facts.

There is an urgent need for independent scientific work to:

- optimise production methods for compost teas
- optimise application strategies for compost teas
- assess the safety and minimise the risks to human health from the use of compost teas
- determine the factors affecting efficacy of compost teas in order to further develop strategies for maximising efficacy

If successful strategies for the production and use of compost teas are developed, there is potential to reduce fungicide costs, to maintain or improve crop growth and health and to improve soil health in field grown crops.

PROJECT AIM AND SPECIFIC OBJECTIVES

The overall aim of this project was:
To answer key questions relating to the preparation, application and effects of compost teas on UK ornamental nurseries and to give growers practical information to enable them to use compost teas to best effect following basic scientific work and glasshouse/tunnel trials.

The specific objectives were as follows:

1. Test the effect *(on crop growth, health and presence/absence of disease*) of teas made using four reputable compost tea brewers (Plates 1 to 4**)** available on the world market on two ornamental species under experimental glasshouse conditions.

Plate 1. The Earth Tea Brewer

Plate 2. The Growing Solutions System 25 brewer

2. Determine the effect *(on crop growth, health and presence/absence of disease*) of compost type on the quality and effects of the finished tea on two ornamental species under experimental glasshouse conditions

3. Determine the effect *(on crop growth, health and presence/absence of disease*) of compost maturity on the quality and effects of the finished tea on two ornamental species under experimental glasshouse conditions

4a. Determine the effect of pre-brewing additives on compost tea performance
4b. Determine the effect of post-brewing additives on compost tea performance

5. Assess the characteristics (*pH, nutrient content, presence of beneficial organisms*) of compost teas used in trials carried out under Objectives 3 and 4.

Plate 3. The van Iersel Xtractor

Plate 4. The Growing Solutions System 25 brewer

6. Test teas made under the two best performing preparation systems (determined under objectives 1-4) on commercial nurseries. The effect of compost teas on the following will be determined:

- Crop growth and development (roots and shoots)
- Crop health (incidence/severity of diseases, presence of pests, pest damage and biological control agents)

7. Prepare a report based on work carried out in this study and an assessment of other important scientific work in the USA and Europe. The report will aim to:

- Briefly review relevant literature on compost teas
- Summarise the results obtained in the project
- Provide guidance to growers on the preparation and use of compost teas
- Determine research priorities for the future

GENERAL MATERIALS AND METHODS

All trials contained four replicates and were laid out in randomised block designs. The growing media used was the same throughout the SAC-based trials and consisted of medium grade fibrous sphagnum peat mixed with dolomitic limestone (2.4 kg/m^3) and Osmocote Exact 15+9+9+3MgO+Te, 8-9 month at 3.5 kg/m^3 (Scotts).

Two species (lavender and choisya) were used throughout the SAC-based trials. The varieties used are named in individual trials. For each trial, a plot consisted of twenty plants of the same species placed in an individual plastic carrying tray lined with 5 cm of sand. The sand in each plot was watered as required in order to keep it damp (i.e. each tray was maintained as an individual sandbed). Pots were kept on individual sandbeds in order to prevent cross-contamination of neighbouring treatments.

Compost teas were prepared as far as possible according to the manufacturer's instructions for each brewer, i.e.
Xtractor (100 l) 46 g compost / l water + contents of van Iersel kit as per instructions
Liquid Compost Brewer: (20 l) 24 g compost / l water + contents of van Iersel kit as above
System 25 (80 l) 11 g compost / l water + contents of van Iersel kit as above
Earth Tea Brewer (70 l) 13 g compost / l water + contents of van Iersel kit as above

The brewers were filled with plain water and run for 3 hours prior to the addition of compost to remove chlorine from the water. Compost was then added (as above) and the brewers run for 24 hours (18 hours for Trials 2, 3, 4a and 4b). Compost teas were filtered (0.4 mm mesh filter) prior to application.

Compost teas (or plain water control) were applied fortnightly in Trial 1, starting on the day of potting, as coarse overhead sprays (5 ml tea/m^2 water or 50 l/ha) diluted 1:5 in water. This was changed for Trials 2, 3, 4A and 4b, in which compost teas were applied as coarse overhead sprays undiluted to run-off. (NB. Application rates were changed for later trials following discussion with Steve Schueurell who achieved good disease control in scientific trials when using undiluted compost teas sprayed in this way.)

Fungicides were applied fortnightly in Trials 1 to 4b in the following programme:
Scotts Octave (46% w/w prochloraz, Scotts) applied at potting (2 g in 1 l water applied as a spray to run-off, equivalent to 220 l /ha)
Bavistin DF (50% w/w carbendazim, BASF) applied 2 weeks after potting (1 g in 1 l water applied as a spray to run-off, equivalent to 220 l /ha)
Aliette 80WG (80% w/w fosetyl aluminium, Aventis) applied 4 weeks after potting (5 g in 5 l water /m^2) as a drench
The above programme was repeated until trial harvest

The sprayer used was a Berthould Vermorel 2000 Pro (Berthould, F-69653 Villefranche-Sur-Saone Cedex, France) with a coarse fan nozzle. Fungicide application programmes used in the nursery trials (Trial 6) varied depending on the nursery concerned. Details are given in Appendix II and III. Trays were removed for treatment application in order to avoid cross contamination of adjoining plots.

Analysis of variance (using Genstat) was carried out on results from all trials. Fischer's protected least significant difference tests ($p < 0.05$) were used to test for differences between paired treatment means.

TRIAL 1 - Effect of teas made using four brewers on ornamentals

Introduction

Almost all of the brewers being used in the UK are of a single model (The Xtractor) imported from The Netherlands from Compara by Fargro. The growers in this country seem generally happy with this model, but there have been no independent UK trials to compare performance of this brewer with performance of the other, more established models from the United States.

The aim of this trial was to test the effect (on crop growth, health and presence/absence of disease) of teas made using four different reputable compost tea brewers available on the world market on two ornamental species under experimental glasshouse conditions. The temperature of the finished teas was measured and microbial numbers were assessed to see whether there were differences between the teas produced by the different brewers. The Xtractor brewer (currently being used by UK ornamentals growers) was one of the four on test.

Materials and methods

Plant species were as follows:
Lavender [*Lavandula angustifolia* 'Imperial Gem']
Choisya [*Choisya ternata* 'Sundance']

Treatments were as follows:

- Tr. 1 plain water applied at same rates as compost teas
- Tr. 2 standard fungicide treatment [see General materials and methods]
- Tr. 3 tea applied with brewer 1 (Liquid Compost Brewer)
- Tr. 4 tea applied with brewer 2 (Xtractor)
- Tr. 5 tea applied with brewer 3 (System 25)
- Tr. 6 tea applied with brewer 4 (Earth tea brewer 22)

Brewers used were as follows:
Liquid Compost Brewer obtained from Compost Tea Brewers Ltd., 42a High Street, Theale, Reading, Berkshire, RG7 5AN, UK
Xtractor (Compara) Obtained from Fargro Ltd., Toddington Lane, Littlehampton, West Sussex, BN17 7PP, UK
System 25 Obtained from Growing Solutions Inc., Michael Alms, 160 Madison Street, Eugene, Oregon 97402, USA
Earth Tea Brewer obtained from EPM Inc., PO Box 1295 Cottage Grove Oregon 97424, USA.

Compost:
The compost used for Trial 1 was obtained from van Iersel (through Fargro, Littlehampton, UK). The other ingredients sold by van Iersel (through Fargro) along with the compost to form a kit (soil food ingredients, numbered 1 to 4) were included in every brew.

Method
The method and assessment protocols for Trial 1 can be found in the Annual Report, which was produced from this project in November 2004.

Results

The full results for Trial 1 were presented in the Annual report which was produced from this project in November 2004. A summary of the results obtained follows:

- There were no differences between the growth (plant height or shoot dry weight) of either lavender or choisya plants treated with fungicides, plain water or compost teas made using four different brewers.
- There were no differences in the amount of disease caused by botrytis on lavender or the amount of two-spotted spider mite (*Tetranychus urticae*) damage on choisya plants treated with fungicides, plain water or compost teas made using four different brewers.
- Plate counts showed that the numbers of total culturable bacteria recorded from brews in Trial 1 were almost always within the range reported for disease suppressive compost teas (i.e. they were between 10^7 to 10^{10} CFU per ml).
- In summary, the type of brewer used had no effect on the quality of lavender or choisya plants or their susceptibility to pests or diseases.

Discussion

There were no significant differences between treatments for any of the parameters tested on either lavender or choisya plants in Trial 1. The plants grew well on the whole, although there was low but increasing levels of disease in the lavenders and two-spotted spider mite damage on the choisyas. Published work from the United States has indicated that use of compost teas can be associated with improved crop health and growth and reduced incidence and severity of disease. However, there are plenty of instances where compost extracts and teas have had no effects or even deleterious effects on plant growth and health (Litterick *et al.,* 2002; Scheuerell & Mahaffee, 2002). There were differences in the level of two-spotted spider mite damage between replicates. Replicates in the central part of the polythene tunnel suffered from greater damage. This may have been due to higher temperatures in that part of the tunnel.

Elaine Ingham of Soil Foodweb Inc. maintains that "poor quality" compost teas will have little or no effect on plant growth or health (Ingham, 2002). Quality in this sense refers to the numbers and diversity of beneficial microorganisms present. However, in this experiment, there is no reason to believe that the compost teas produced (or the compost teas used to produce them) were of poor quality. The numbers of total culturable bacteria (on nutrient agar) were within the range which is reported to be associated with disease suppression and varied between $1.1 3^{7}$ to $1.1 0^{8}$ CFU /ml (see discussion Trial 2 for further information). Van Iersel compost was used, two of the brewers (the Earth Tea Brewer and the System 25) have been shown to produce effective teas and the brewing methods were those recommended by the manufacturers. Good quality plants were used in standard growing media and growing conditions for the crop were as used in commercial nursery practice.

It has been suggested that compost teas should ideally be applied within a few hours of brewing, since microorganisms start to die shortly after brewing ceases (Ingham, pers. comm.). No published evidence of work of this type has been found. However the brews in Trial 1 were applied immediately after brewing, in late afternoon when the strength of the sun had decreased after midday. Elaine Ingham has said that compost teas should ideally be applied in the morning or evening (not during strong sun), since microorganisms tend to die more easily on the leaf in strong sunlight (Ingham, 2002). Again, we have not found published evidence of work to prove this, but followed her guidance, since it did make scientific sense.

In this trial, compost teas were prepared exactly according to the recipe devised by van Iersel. The company assures us that this recipe has been tested and developed in order to optimise performance of the finished teas. Unfortunately, the results of this work have not been published and are not available for independent assessment (presumably due to an understandable wish for company confidentiality). However, it may be that the brewing additives used are adversely affecting performance of the teas in some way. Further tests may reveal whether this is the case.

In Trial 1, compost teas were applied as coarse overhead sprays (5 ml tea/m^2 water or 50 l/ha) diluted 1:5 in water. Discussion with Steve Scheuerell (a consultant to this project) confirmed that compost tea users in the United States often apply compost teas at this rate, diluted in sufficient water to cover the crop. However, his own experience using compost teas to successfully control disease involved spraying undiluted teas to run-off. Future trials will use compost teas in this way, since this practice will ensure maximum coverage of leaves and may provide the best possible chance of seeing differences between treatments.

TRIAL 2 - Effect of compost type on the efficacy of compost tea

Introduction

Growers in the UK are almost exclusively using a compost purchased from Van Iersel in the Netherlands (*via* the UK company Fargro). This compost is based on greenwaste. It contains no animal manures and is imported in small quantities at very high cost (in comparison to the cost of similar composts produced in the UK). Such reliance on a single brand of compost is not ideal since growers would be left with no alternative should van Iersel go out of business or should they choose to increase compost price.

The aim of this trial is to determine the effect (on crop growth, health and presence/absence of disease) of compost type on the quality and effects of the finished tea on two ornamental species under experimental glasshouse conditions. The van Iersel compost (currently being used by UK ornamentals growers) was one of the four on test.

Materials and methods

Plant species were as follows:
Lavender Lavender [*Lavandula angustifolia* 'Hidcote']
Choisya [*Choisya ternata* 'Sundance']

Treatments were as follows:

- Tr. 1 plain water applied at same rate as compost teas
- Tr. 2 standard fungicide treatment [see General materials and methods]
- Tr. 3 tea made from compost (CMC compost i., van Iersel)
- Tr. 4 tea made from compost (CMC compost ii.)
- Tr. 5 tea made from compost (greenwaste compost i)
- Tr. 6 tea made from compost (greenwaste compost ii)

NB: van Iersel compost (Treatment 3) is made by the patented Controlled Microbial Composting (or CMC) process. Several UK farming companies make compost using the same process. The compost in Treatment 4 was obtained from an organic farm in Scotland and was made from a mixture of strawy cattle manure, greenwaste and grass clippings. The compost in Treatments 5 and 6 were made outdoors in turned windrow systems similar to those used to produce CMC compost. They were taken from separate UK composting facilities (both of which were accredited with the UK Composting Association as compliant with BSI PAS100) and were made solely from greenwaste similar to that used (as far as can be ascertained) by van Iersel to make their compost.

Brewers used

No differences were observed between the performance of compost teas made using different brewers in Trial 1. The Xtractor was therefore chosen to produce tea for Trial 2, since it is the one used by most UK growers.

Method

The method and assessment protocols for Trial 2 can be found in the Annual Report, which was produced from this project in November 2004.

Results

The full results for Trial 2 were presented in the Annual Report, which was produced from this project in November 2004. A summary of the results obtained follows:

- Lavender plants treated with fungicides had significantly higher quality scores than those treated with plain water or compost tea made from the van Iersel compost.
- Lavender plants treated with compost tea made from the van Iersel compost or greenwaste compost ii. had significantly fewer flower spikes than those treated with fungicides or greenwaste compost.
- Lavender plants treated with fungicides or compost tea made from CMC compost ii. had higher shoot dry weights than those treated with plain water or compost tea made from the van Iersel compost.
- The lavenders in Trial 2 were infected with botrytis, but there were no significant differences between treatments.
- There were no significant differences between treatments for any of the parameters measured on choisya plants (plant height, number of terminal shoots, shoot dry weight at harvest, damage caused by two-spotted spider mite).
- Plate counts showed that the numbers of total culturable bacteria recorded from brews in Trial 2 were almost always within the range reported for disease suppressive compost teas (i.e. they were between 10^7 to 10^{10} CFU per ml).
- In summary, the effect of compost type used to make tea on the quality of lavender or choisya plants and on their susceptibility to pests or diseases was complex. There were frequently no differences in observed parameters between treatments. Where treatment differences were observed, the poorest quality plants were usually those treated with tea made from van Iersel compost.

Discussion

Lavender plants treated with fungicides had significantly higher quality scores than those treated with plain water or compost tea made from the van Iersel compost. Lavender plants treated with compost tea made from the van Iersel compost or greenwaste compost ii. had significantly fewer flower spikes than those treated with fungicides or greenwaste compost i. Finally, lavender plants treated with fungicides or compost tea made from CMC compost ii. had higher shoot dry weights than those treated with plain water or compost tea made from the van Iersel compost. Although the lavenders in Trial 2 were infected with botrytis, there were no significant differences between treatments. There were no significant differences between treatments for any of the parameters measured on choisya plants.

The protocols being used in Trial 2 were based on best practice for compost teas which has been developed in the United States. Some of this best practice is based on published research, whereas some information is currently coming from consultants reports on websites and through personal communication. Again (as with Trial 1), the plants, growing media and composts used to make teas were of best available quality and were stored in cool dark conditions prior to use. The crop husbandry was managed and compost tea applications were made by an experienced horticultural technician. The staff of this project can think of nothing to indicate that anything they might have done may have affected the way in which the teas performed.

In addition to published work which has demonstrated beneficial effects of compost teas, several key UK growers and consultants continue to be convinced of the value of compost teas in improving crop health and growth. Their experience is based on observations rather than on results of replicated trials, but there is no reason to doubt their convictions. It is recognised that disease pressure is often higher on nurseries where large areas of single crops are grown and differences in disease pressure may influence the effects which compost teas have.

Microbial populations in compost tea are thought to be the most significant factor contributing to disease suppression. However, there is very little published information available on the microbial species composition of compost tea and how these organisms survive on plants surfaces (Scheuerell and Mahaffee, 2002). This lack of understanding likely contributes to the variable efficacy often reported for controlling plant pathogens with compost teas. Standard methods for reporting compost tea microbial populations have not been established and this further adds to the confusion, since comparisons across experimental systems are not possible. The numbers of total culturable bacteria reported from disease suppressive compost tea (NCT) vary with a range of 10^7 to 10^{10} CFU per ml. Microbial counts made from brews in Trials 1 and 2 indicate that bacterial numbers were usually within that range. However, variable disease suppression has been reported even where brews (NCT and ACT) are known to contain between 10^9 to 10^{10} CFU per ml. (Scheuerell, unpublished data).

Variability in bacterial species might be a cause of variable efficacy in disease control when using teas, but more work is required if a relationship is to be established between populations of specific microorganisms and disease control or improved plant growth/health. Work is also required to determine how to produce composts with a suitable balance of microbial species to produce reliably effective compost teas.

TRIAL 3 - Effect of compost maturity on the efficacy of compost tea

Introduction

Indications from work on composts have suggested that their disease suppressive effects are dependent on their maturity (Litterick *et al*., 2003; Nelson *et al*., 1983). Since it is recognised that the microflora of compost teas is dependent on that within the compost from which they are made, the maturity of composts used to make compost tea may be important. This trial therefore aimed to determine the effect (on crop growth, health and presence/absence of disease) of compost maturity on the quality and effects of the finished tea on two ornamental species under experimental glasshouse conditions.

Materials and methods

<u>Plant species were as follows:</u>
Lavender Lavender [*Lavandula angustifolia* 'Hidcote']
Choisya [*Choisya ternata* 'Sundance']

<u>Treatments were as follows:</u>

- Tr. 1 plain water applied at brewer rates
- Tr. 2 standard fungicide treatment [see General materials and methods]
- Tr. 3 tea made from compost 1 (CMC compost i., van Iersel)
- Tr. 4 tea made from compost 2 (greenwaste, immature)
- Tr. 5 tea made from compost 3 (greenwaste, mature)
- Tr. 6 tea made from compost 4 (greenwaste, very mature)

NB: Composts 2, 3 and 4 were taken from a commercial greenwaste compost production facility in the UK. The immature compost was taken from a 10 week old windrow. The mature compost was taken from a windrow which was 3 months old and the very mature compost was taken from a windrow which was 2 years old. The same composts were used throughout the trial and were stored at 10-15^{o}C in a dark room during the period of the trial. Compost stability/maturity was confirmed by testing for carbon dioxide evolution using the method developed by ADAS Direct labs (WRAP, 2003). The results are shown in Table 1.

Table 1. Carbon dioxide evolution rates from composts used in Trial 3

Compost	CO_2 evolution (mg CO_2/g volatile solids/day)	Indication
1 (CMC compost i., van Iersel)	3.1	Mature compost
2 (greenwaste, immature)	11.3	Immature compost
3 (greenwaste, mature)	5.8	Mature compost
4 (greenwaste, very mature)	2.8	Very mature (old) compost

Nutritional analysis was also carried out on the composts and teas used in this experiment. Results are shown under Objective 5 (Tables 4 and 5).

Brewers used

Since no differences were observed between the performance of compost teas made using different brewers in Trial 1, two brewers were used in Trial 3 (the Xtractor and the System 25). The Xtractor was used to produce tea for Treatment 3 on potting day and Treatment 4 on the following day. The System 25 was used to produce tea for Treatment 5 on potting day and Treatment 6 on the following day. The same procedure was repeated each fortnight, although the brewers were alternated for the treatments each fortnight (e.g. the Xtractor was used to prepare Treatments 5 and 6 on the second treatment date).

Method

- The trial was set up on Tuesday 21 September 2004.
- 480 choisya and 480 lavender plugs were potted into 8 cm square pots
- 20 plants of the same species were placed in individual plastic carrier trays lined with 5 cm of sand (to simulate individual sandbeds). One tray of each made up a plot.
- Each tray was labelled with treatment and replicate numbers
- The trays were placed in a randomised block design on the floor of a polythene tunnel (temperature range 10 - 30^{o}C)
- Compost teas (or plain water control) were applied fortnightly starting on the day of potting, as coarse overhead sprays undiluted to run-off. NB. Trays were removed for treatments to avoid cross contamination of adjoining treatments.
- Fungicides were applied as in commercial practice to plants in Treatment 2

Assessments

- Plants were checked for incidence of pests and diseases weekly. If present, the severity of pest or disease attack was quantified using the following numerical scoring systems:

Two-spotted spider mite damage scoring system for chosyia

0 = no two-spotted spider mite

1 = spider mite evident on lower leaves

2 = spider mite evident on lower leaves up to leaf tips, no leaf damage evident

3 = damage to leaf tips, some distortion
4 = as above, plus webbing evident on leaves
5 = as above, severe webbing, leaves discoloured

Botrytis scoring system for lavender
0 = no botrytis
1 = 1 - 10 basal leaves dead with visible botrytis. Sporulation present
2 = > 10 basal leaves dead with visible botrytis as above
3 = 1 stem dying or dead, with visible botrytis as above
4 = 2 stems as above
5 = 3 " " "
6 = 4 " " "
7 > 4 " " "
8 = plant dead

- Mildew scoring system for choisya:
  0 = no mildew
  1 = 1 - 3 leaves affected with mildew but no browning on leaves
  2 = 4 - 6 leaves affected with mildew, but no browning leaves
  3 = > 6 leaves affected by mildew with some browning on leaves
  4 = 10 leaves affected by mildew with some browning on leaves
  5 > 20 leaves affected by mildew, severe browning on leaves, evidence of leaf drop.

- Plant growth was assessed 27 weeks after the start of the trial by measuring plant height (mm), plant quality and the number of terminal shoots (choisya). Lavenders were assessed for quality, number of flower spikes per plant and number of side shoots. The quality scoring system for both plant species was as follows:

  Plant quality scoring system (Trials 3 and 4)
  0 = dead plant
  1 = plant unsaleable due to small size and/or, presence of brown shoots
  2 = plant badly distorted in shape with some brown areas
  3 = plant has no brown areas, but shape uneven
  4 = plant has no brown areas, but size or shape not of top quality
  5 = robust healthy plant of good size
- Destructive assessments (shoot dry weights) were made 27 weeks after the start of treatment.

Results

There were no differences in plant height, plant quality or number of shoots between treatments on either lavender or choisya 2 and 4 months after the trial was set up. There was no evidence of any disease or pest damage 2 or 4 months after potting. The trial was allowed to run for longer than originally intended in order to see whether differences developed between treatments. It was harvested 6 months after it was set up and the results from assessments are described below.

The lavender plants were of poor to moderate quality (due to botrytis, mean quality score 2.5) but there were no significant differences between treatments. Botrytis was found in all treatments (mean disease score was 3.0, i.e. an average of one stem dying or dead, with visible botrytis present) but again there were no significant differences between treatments. Similarly, there were no significant differences between the number of flower spikes, plant height or shoot dry weight recorded between treatments.

Statistical analysis (ANOVA) showed that there were significantly more side shoots on lavender plants treated with compost tea made with young compost than on those in other treatments. Lavender plants treated with compost tea made with van Iersel compost, mature compost or fungicide had the lowest number of side shoots (Figure 1).

The choisya plants were of good quality (mean quality score 4.5 on 14 February 2005) until disease (powdery mildew) was recorded towards the end of the trial period. Up until disease was recorded, there were no significant differences between quality scores recorded in different treatments. Similarly, there were no significant differences between shoot dry weight or number of stems recorded on plants in each treatment immediately prior to harvest. Powdery mildew was found in all treatments after the beginning of March 2005. Statistical analysis (ANOVA with transformations) showed that plants treated with plain water, fungicide or compost tea made either van Iersel compost or old greenwaste compost had significantly lower levels of mildew than those treated with compost tea made with either young or mature compost (Figure 2).

Statistical analysis (ANOVA with transformations) showed that there were significant differences between the height of choisya plants in different treatments ($P = 0.045$, Figure 3). Plants treated with plain water or fungicides were significantly smaller than those in other treatments.

Statistical analysis (ANOVA with transformations) showed that there were significant differences between the amount of damage caused by two-spotted spider mite on choisya plants at harvest ($P = 0.027$, Figure 4). Choisya plants treated with compost tea made with van Iersel compost had significantly greater spider mite damage than those in other treatments. Plants treated with plain water, fungicides or compost tea made from old greenwaste compost had the least damage due to spider mites.

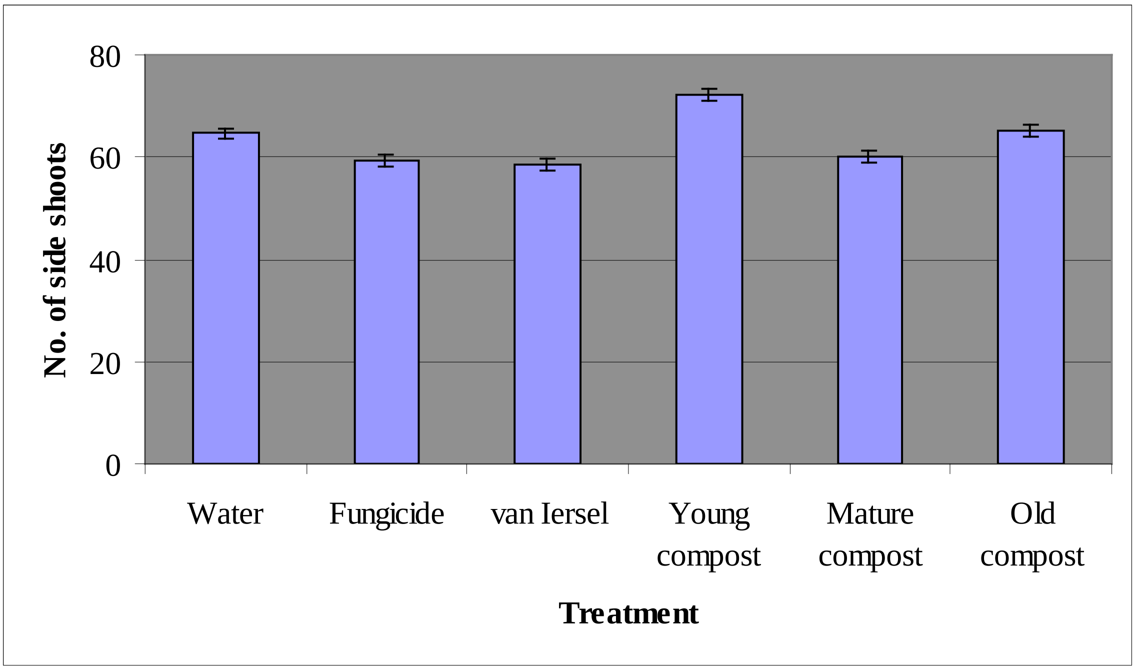

Figure 1. Effect of age of compost used to make tea on the number of side shoots in lavender 6 months after potting (Trial 3). Error bars represent standard error of the mean (SEM).

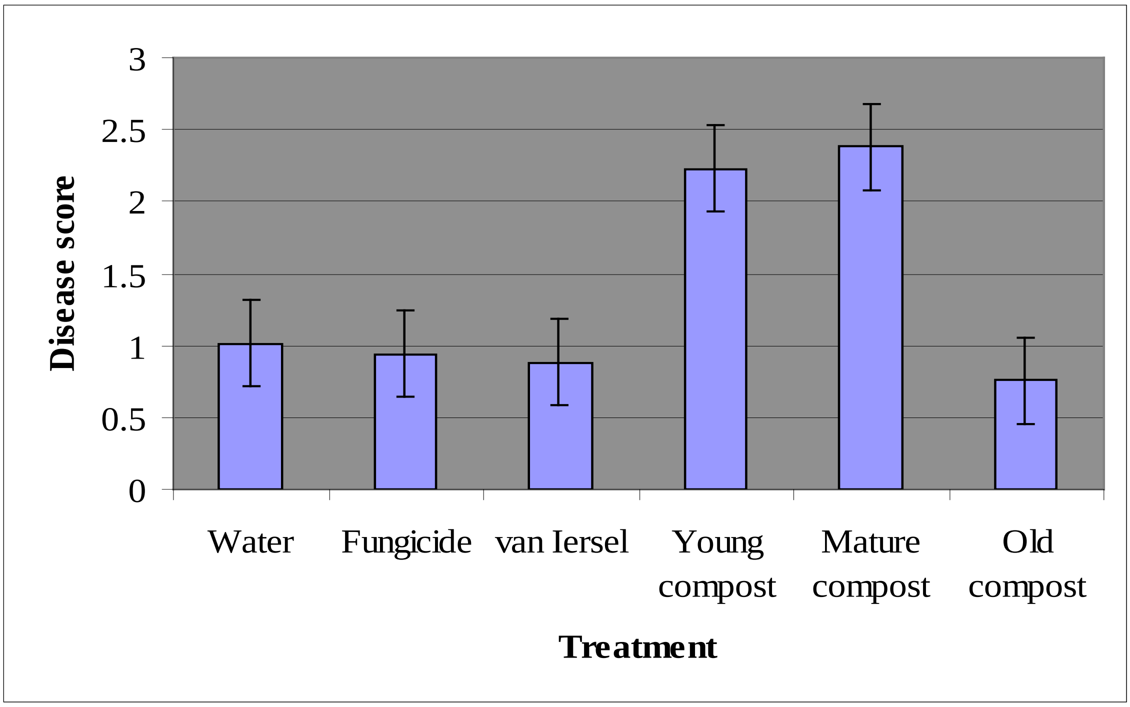

Figure 2. Effect of age of compost used to make tea on disease caused by powdery mildew on choisya plants 6 months after potting (Trial 3). Disease score: 0 = no mildew; 1 = 1 - 3 leaves affected with mildew but no browning on leaves; 2 = 4 - 6 leaves affected with mildew, but no browning leaves; 3 = > 6 leaves affected by mildew with some browning on leaves; 4 = 10 leaves affected by mildew with some browning on leaves; 4 = > 20 leaves affected by mildew with severe browning on leaves and evidence of leaf drop. Error bars represent standard error of the mean (SEM).

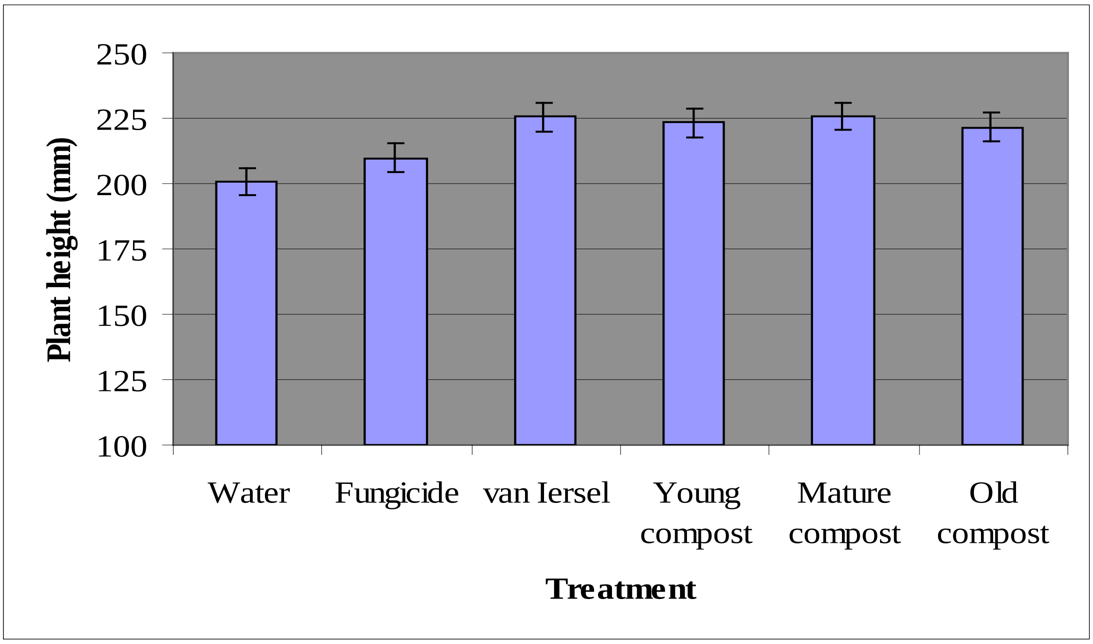

Figure 3. Effect of age of compost used to make tea on the height of choisya plants 6 months after potting (Trial 3). Error bars represent standard error of the mean (SEM).

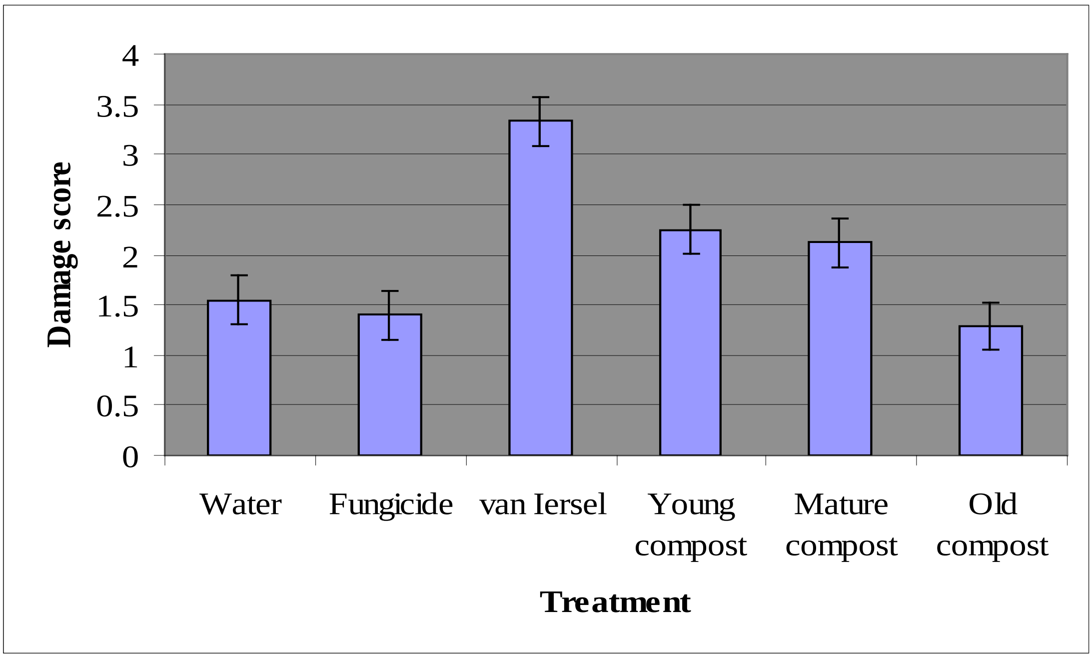

Figure 4. Effect of age of compost used to make tea on the amount of damage caused by two-spotted spider mites on choisya (Trial 3). Damage scoring system as follows: 0=No two-spotted spider mite; 1=spider mite evident on lower leaves; 2=spider mite evident on lower leaves up to leaf tips, no leaf damage evident; 3=damage to tip leaves, some level of distortion; 4=as above, plus webbing evident on leaves; 5=as above, severe webbing, leaves discoloured. Error bars represent standard error of the mean (SEM).

Discussion

There were no significant differences between plant height, plant quality or disease incidence on either lavender or choisya during the first 5 months of the trial. Liners of nursery stock species including lavender and choisya would often be potted after 4 or 5 months, but none of the compost teas tested had any effect within this timescale.

Significant differences were found between treatments in terms of the number of side shoots (lavender) and in terms of plant height, the amount of mildew and the amount of two-spotted spider mite damage (choisya). Although differences were observed, there were no clear benefits in terms of overall plant quality from using compost tea made from any particular compost. Lavenders treated with compost tea made with young greenwaste compost had the greatest number of side shoots. Choisyas treated with tea made from either young or mature greenwaste compost had significantly more mildew than those in other treatments. Choisya plants treated with tea made from any of the four composts tested were generally taller than those treated with fungicide or plain water. Finally, choisya plants treated with tea made from van Iersel compost suffered significantly greater two-spotted spider mite damage than those in other treatments.

Although limited benefits were found from treating lavender or choisya plants with compost tea for more than 5 months, there was no clear relationship between the type of compost used and overall plant quality. For example, although choisya plants treated with tea made with van Iersel compost were significantly taller than those treated with water or fungicide and had significantly less powdery mildew than those treated with tea made with young or mature greenwaste compost, they also had significantly greater levels of two-spotted spider mite damage.

Carbon dioxide evolution tests carried out on the compost used to make teas in this trial indicated that the van Iersel compost is a mature compost. Its respiration rate was lower than that recorded in the compost which was labelled as mature, but higher than that recorded in the compost which was labelled as very mature or old (Table 1). The results from this trial indicated that there was no clear relationship between the stability of compost used to make teas (as measured by the CO_2 evolution test) and the quality of treated lavender and choisya plants.

TRIAL 4a Effect of pre-brewing additives on the performance of compost teas

Introduction

Evidence from the United States has shown that additives put in prior to brewing can have a significant effect on the performance of the finished tea. The components of the van Iersel kit (supplied with their compost and used by UK ornamentals growers) may have been tested individually to confirm their effects/usefulness, but if so, the results have not been published and are not available for independent appraisal.

Many compost tea recipes from the USA include sugars (in the form of molasses). Some include humates and/or seaweed extract. The addition of herbs is much less common in standard compost tea recipes from the USA. However, five herbs plus oak bark are used to make the biodynamic "compost and manure preparations" which are used to improve the composting process and the plants to which they are applied in biodynamic farming systems (Koepf, 1989). The five herbs used are camomile (*Matricaria chamomilla*), dandelion (*Taraxacum officinalis*), stinging nettle (*Urtica dioica*), valerian (*Valeriana officinalis*) and yarrow (*Achillea millefolium*). The compost produced by van Iersel is understood to be produced according to the CMC method, which was devised by a biodynamic farming family, therefore it was thought that the herbs used by van Iersel might be those used in biodynamic preparation 501. This looks likely, since flower parts from chamomile and yarrow were identified within the herb mix supplied by van Iersel.

It has not proved possible to determine the exact nature of the additives which van Iersel sell as "essential" constituents of their compost tea kits (Plate 5). This is presumably due to commercial confidentiality. However, study of a range of information sources on compost tea production and biodynamic farming (Diver 1998, 2001; Ingham, 2002; Koepf, 1989) have led us to be fairly certain that the four additives sold by van Iersel include sugars, nutrients (humates and seaweed extracts) and herbs.

It is important that the formulation of brews (pre-brewing) is tested under UK conditions in order to ensure that compost teas are used to best effect. The aim of Trial 4a was to determine the effect of brew constituents on the performance of compost teas.

Plate 5. Constituents of the kit supplied by van Iersel (containing compost and containing pre-brewing additives

Materials and methods

Plant species were as follows:

Lavender Lavender [*Lavandula angustifolia* 'Hidcote']

Choisya [*Choisya ternata* 'Sundance']

Treatments:

- Tr. 1 plain water applied at brewer rates
- Tr. 2 standard fungicide treatment [see General materials and methods]
- Tr. 3 van Iersel Kit mixture (Van Iersel compost + herbs + sugars + nutrients)
- Tr. 4 van Iersel compost + herb mix + sugars + nutrients (see below for details)
- Tr. 5 CMC compost + herb mix + sugars + nutrients (as above)
- Tr. 6 CMC compost + sugars + nutrients (as above, no herbs)

Treatment details

Additives added in treatments 4, 5 and 6 included: molasses, biohumates (Biotechnica, Reading, UK), seaweed extracts (Maxicrop, Corby, UK) and a herb mixture (containing camomile (*M. chamomilla*), dandelion (*T. officinalis*), stinging nettle (*U. dioica*), valerian (*V. officinalis*), yarrow (*A. millefolium*) and oak bark (*Q. robur*). All additives were mixed into brews at the same rate as their equivalents in the van Iersel kits. See "Current situation" section for reasons as to why these additives were chosen.

Method

- Trial 4a was set up on 18 October 2004.
- 480 choisya and 480 lavender plugs were potted into 8 cm square pots. Individual trays were labelled with treatment and replicate numbers
- Trays were placed on the floor of a glasshouse (temperature range 15-25^{o}C) and treatments were applied as recorded in the general materials and methods.

Assessments

- Plants were checked for incidence of pests and diseases weekly. If present, the severity of pest or disease attack was quantified using the scoring systems used in Trial 3.
- Plant growth was assessed 2, 4 and 6 months after the start of the trial by measuring plant height (mm) and plant quality (using the scoring system used in Trial 3).
- Destructive assessments (shoot dry weights) were made 6 months after the start of treatment.

Results

There were no significant differences in the height or quality of lavender plants or the amount of disease present between treatments at any point during the 6 month trial period. Lavenders were harvested after 6 months. The mean shoot dry weight per plant over the whole trial was 18.1 g, but there were no significant differences in the mean shoot dry weights obtained for the six treatments. The mean height and quality scores recorded for lavender plants over the whole trial were 210 mm and 2.7 respectively. Again, there were no significant differences in either plant height or quality scores between the six treatments at harvest. There was botrytis present in all treatments (mean disease score over the whole trial was 2.6) but there were no significant differences in the mean amount of botrytis recorded between the six treatments.

There were no significant differences in the height or quality of choisya plants during the first 5 months of the trial period. There was no pest damage, disease incidence or foliar scorch recorded on the choisya plants throughout the trial period.

There were significant differences in the quality of choisya plants between treatments (Figure 5). Plants treated with fungicide were of significantly better quality than those in all other treatments. Plants treated with compost teas made with van Iersel compost or CMC compost made with the herb mix, sugar and nutrients were of significantly poorer quality than those in other treatments.

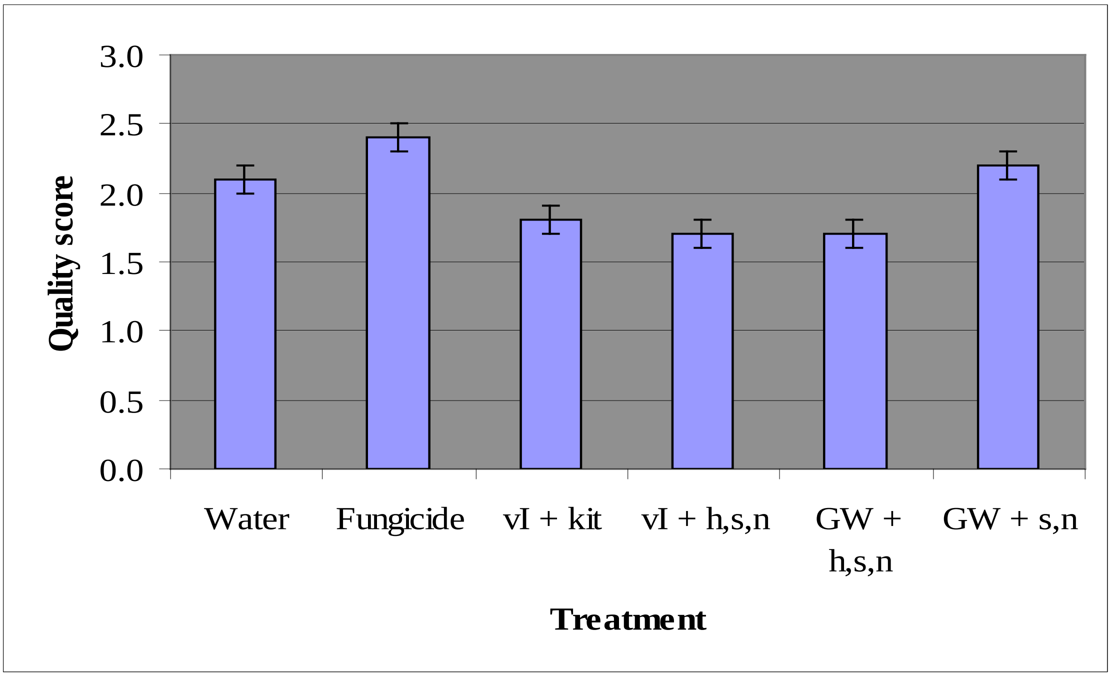

Figure 5. Effect of pre-brewing additives on the quality score of choisya plants 6 months after potting and treated fortnightly with compost tea (Trial 4a). [Tr. 3 (vI + kit) = van Iersel Kit mixture (Van Iersel compost + herbs + sugars + nutrients); Tr. 4 (vI + h, s, n) = van Iersel compost + herb mix + sugars + nutrients; Tr. 5 (GW + h,s,n) = CMC greenwaste compost + herb mix + sugars + nutrients (as above); Tr. 6 (GW + s,n) = CMC greenwaste compost + sugars + nutrients (as above, no herbs)]. Error bars represent standard error of the mean (SEM).

There were significant differences in the shoot dry weight of choisya plants between treatments (Figure 6). Plants treated with compost teas were significantly heavier than those treated with plain water or fungicide.

Discussion

There were no significant differences between plant height, weight, quality or disease incidence on lavender plants between treatments in this trial. There were no significant differences between plant height or quality in choisya plants during the first 5 months of the trial and no pests or disease recorded throughout the trial. Since many liner crops would be potted on within 5 months of being put into liner pots, it is doubtful that a commercial grower would see any benefits from the use of compost teas if their lavender and choisya crops were grown under similar conditions to those in this trial.

There were no significant differences between plants treated with compost teas containing different brewing additives, with the following exception. Choisyas treated with tea made from CMC compost with herbs, sugars and nutrients were of significantly better quality than those made from CMC with sugars and nutrients alone (and those made from both van Iersel preparations).

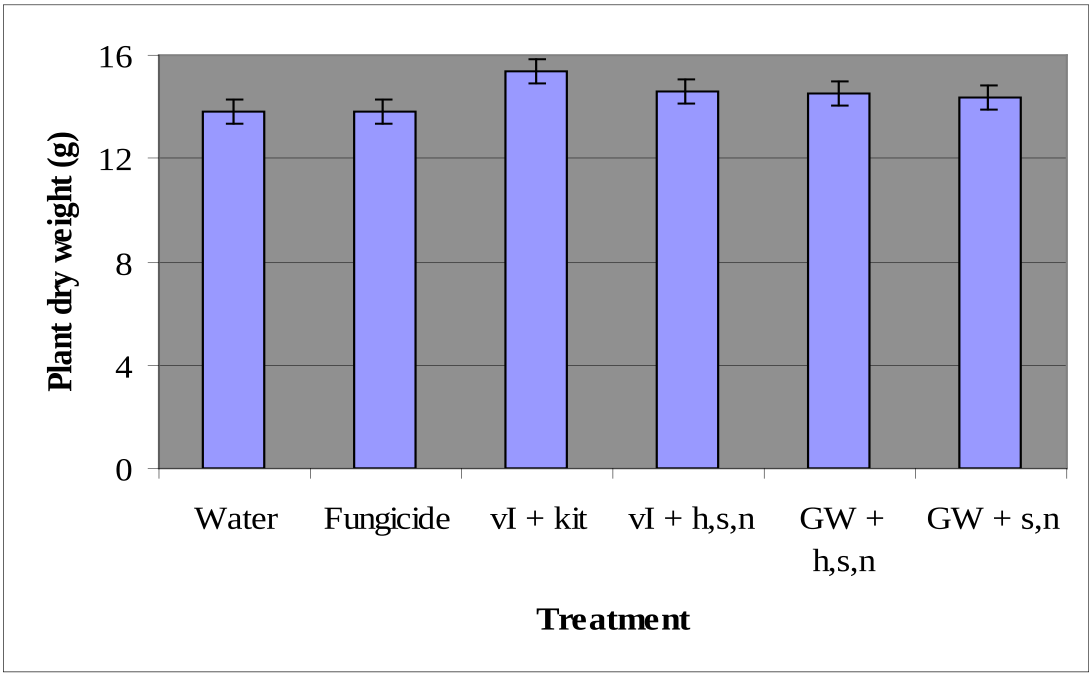

Figure 6. Effect of pre-brewing additives on the shoot dry weight of choisya plants 6 months after potting and treated fortnightly with compost tea (Trial 4a). [Tr. 3 (vI + kit) = van Iersel Kit mixture (Van Iersel compost + herbs + sugars + nutrients); Tr. 4 (vI + h, s, n) = van Iersel compost + herb mix + sugars + nutrients; Tr. 5 (GW + h,s,n) = CMC greenwaste compost + herb mix + sugars + nutrients (as above); Tr. 6 (GW + s,n) = CMC greenwaste compost + sugars + nutrients (as above, no herbs)]. Error bars represent standard error of the mean (SEM).

Results from this trial showed that there were no differences between performance of teas made with van Iersel composts with the proprietary pre-brewing kit and van Iersel composts made with similar, separately obtained pre-brewing additives. Results also showed that there were no differences between performance of teas made with CMC composts, herbs, sugar and nutrients and van CMC composts made sugar and nutrients alone.

In summary, there is insufficient evidence to show that differences in pre-brewing additives have any effect on the performance of compost teas.

TRIAL 4b Effect of post-brewing additives on the performance of compost teas

Introduction

Several consultants in the United States recommend that post brewing additives are added to compost teas prior to application. There is some disagreement on which additives are most appropriate and no published evidence to demonstrate effects of post-brewing additives. The aim of this trial was to determine whether post-brewing additives affected the performance of compost teas.

Materials and methods

<u>Plant species were as follows:</u>
Lavender Lavender [*Lavandula angustifolia* 'Hidcote']
Choisya [*Choisya ternata* 'Sundance']

<u>Treatments:</u>

- Tr. 1 plain water applied at brewer rates
- Tr. 2 standard fungicide treatment
- Tr. 3 van Iersel compost + kit mixture
- Tr. 4 van Iersel compost + kit mixture + Codacide oil (95 % vegetable oil, Microcide, Bury St. Edmunds, UK)
- Tr. 5 van Iersel compost + kit mixture + methyl cellulose (Analar, UK)
- Tr. 6 van Iersel compost + kit mixture + TOIL (95% w/w methylated rapeseed oil, Interagro, Bishop's Stortford, UK)

The Xtractor was used to produce tea for Treatments 3, 4, 5 and 6 on all dates.

<u>Method</u>

- Trial 4b was set up on March 26th 2005.
- 480 choisya and 480 lavender plugs were potted into 8 cm square pots. Individual trays were labelled with treatment and replicate numbers
- Trays were placed on the floor of a glasshouse (temperature range 15 - 25^{o}C) and treatments were applied as recorded in the general materials and methods.

<u>Assessments</u>

- Plants were checked for incidence of pests and diseases weekly. If present, the severity of pest or disease attack was quantified using the scoring systems used in Trial 3.
- Plant growth was assessed 2, 4 and 6 months after the start of the trial by measuring plant height (mm) and plant quality (using the scoring system used in Trial 3)

- Destructive assessments (shoot dry weights) were made 6 months after the start of treatment.

Results

There were no significant differences in the height or quality of lavender plants or the amount of disease present between treatments at any point during the 6 month trial period. The mean shoot dry weight per plant at harvest over the whole trial was 20.7 g, but there were no significant differences in the mean shoot dry weights obtained for the six treatments. The mean quality scores recorded for lavender plants over the whole trial were 2.7. There was no significant difference in plant quality between the six treatments at harvest. There was botrytis present in all treatments (mean disease score over the whole trial was 2.6) but there were no significant differences in the mean amount of botrytis recorded between the six treatments.

There were no significant differences in the height or quality of choisya plants during the first 5 months of the trial period. There was no pest damage, disease incidence or foliar scorch recorded on the choisya plants throughout the trial period. There were significant differences in the quality of choisya plants between treatments at harvest. (Figure 7). Plants treated with compost tea made with van Iersel compost without post-brewing additives were of significantly higher quality than those treated with van Iersel compost with post-brewing additives.

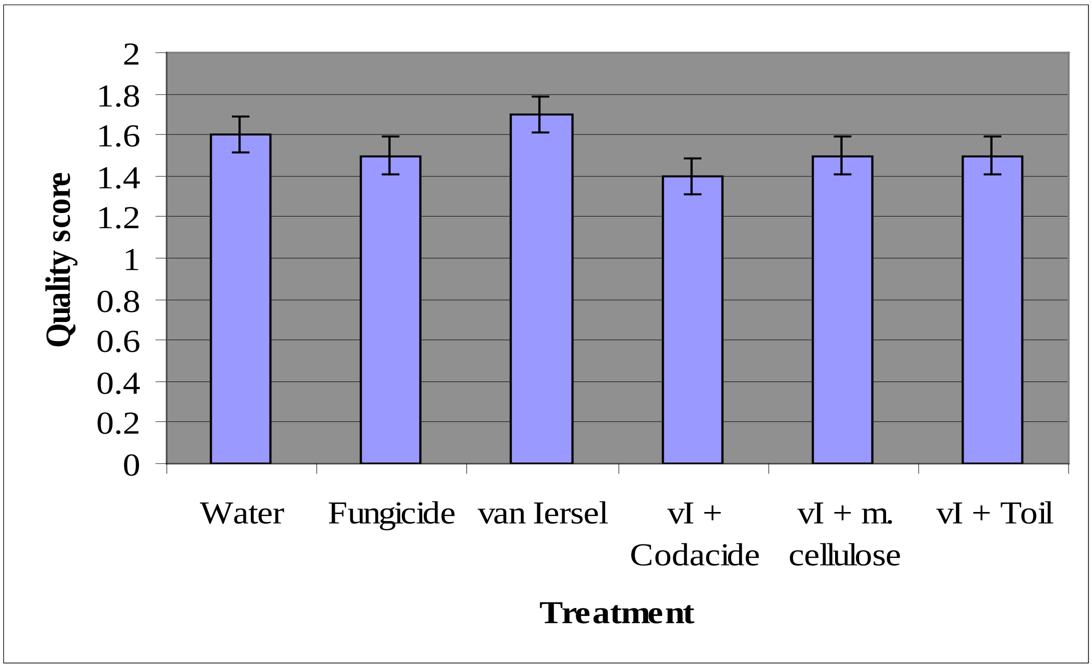

Figure 7. Effect of post-brewing additives on the quality score of choisya plants 6 months after potting and treated fortnightly with compost tea (Trial 4b). [Tr. 3 = tea made with van Iersel Kit mixture only; Tr. 4 (vI + codacide) = tea made with van Iersel kit mix + codacide oil; Tr. 5 (vI + m cellulose) = tea made with van Iersel kit mix + methyl cellulose; Tr. 6 (vI + Toil) = tea made with van Iersel kit mix + Toil. Error bars represent standard error of the mean (SEM).

There were significant differences in the shoot dry weight of choisya plants between treatments (Figure 8). Plants treated with compost teas applied with brewing additives were significantly heavier than those treated with plain water, fungicide or compost tea applied without brewing additives.

Discussion

There were no significant differences between plant height, weight, quality or disease incidence on lavender plants between treatments in this trial. There were therefore no differences between performance of teas made with and without brewing additives when used on lavender plants.

There were no significant differences between plant height or quality in choisya plants during the first 5 months of the trial and no pests or disease recorded throughout the trial. Many liner crops would be potted on within 5 months of being put into liner pots. It is therefore doubtful that a commercial grower would see any benefits from the use of any of the compost teas applied in this trial if their lavender and choisya crops were grown under similar conditions to those in this trial.

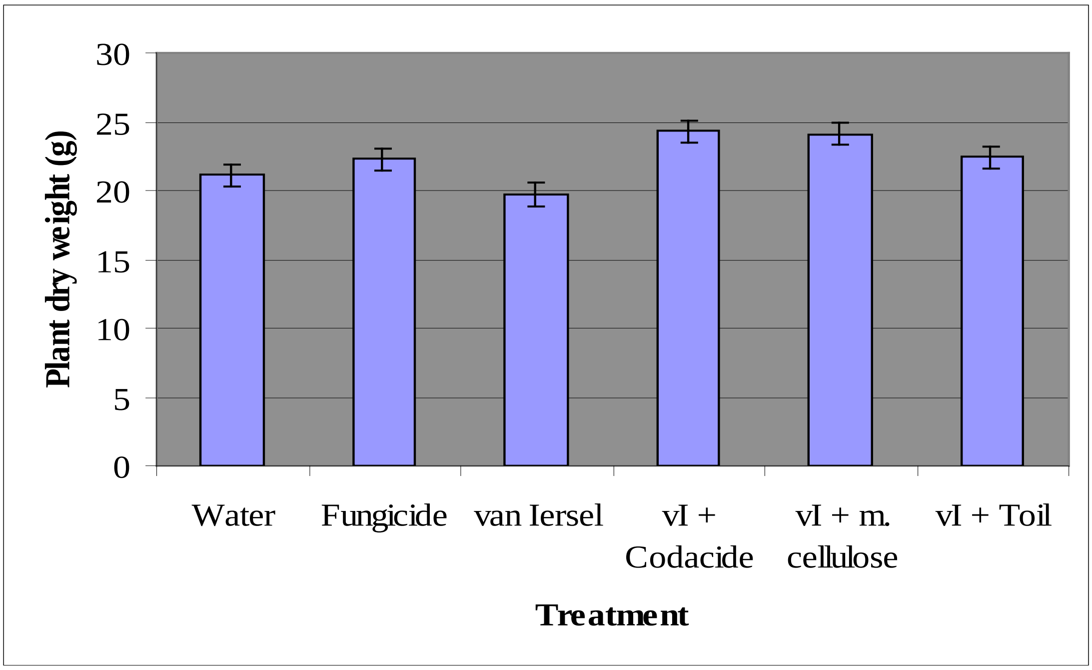

Figure 8. Effect of post-brewing additives on the shoot dry weight of choisya plants 6 months after potting and treated fortnightly with compost tea (Trial 4b). [Tr. 3 = tea made with van Iersel Kit mixture only; Tr. 4 (vI + codacide) = tea made with van Iersel kit mix + codacide oil; Tr. 5 (vI + m cellulose) = tea made with van Iersel kit mix + methyl cellulose; Tr. 6 (vI + Toil) = tea made with van Iersel kit mix + Toil. Error bars represent standard error of the mean (SEM).

Choisyas treated with compost tea containing brewing additives were significantly heavier than those made with van Iersel compost alone. However, choisyas treated with compost tea made with van Iersel compost without post-brewing additives were of significantly higher quality than those treated with van Iersel compost with post-brewing additives. In other words, although plants treated with compost tea with brewing additives tended to be heavier, those treated with compost tea with no brewing additives tended to be shorter and more compact.

OBJECTIVE 5 - Assess the characteristics of compost teas used in trials

Introduction

There is very little scientific information available on the biological and chemical characteristics of compost teas. It is currently possible to send samples of compost teas off to the Soil Foodweb Labs in the United States or in The Netherlands for microbiological testing. However, this involves significant delays (due to postage/courier times) between producing and testing the teas. In addition, due to the commercial nature of the laboratories involved, there is very little published information available on the biological and chemical characteristics of compost teas made using different composts, brewers, brew constituents and techniques.

There is a need to gather information about the chemical and biological characteristics of compost teas in an effort to determine the characteristics of "good" teas and "bad" teas. This information may help us develop methods for making reliably effective compost teas. Work under objective 5 aimed to assess the physical, chemical and biological characteristics of composts and compost teas used in trials carried out in this project.

Materials and methods

Microbial analyses were performed on selected compost teas from the Trials 1, 2 and the nursery trials (Trial 6). Samples were stored at $4^{o}C$ immediately upon arrival from SAC, and stored for up to 3 weeks prior to analysis. Serial dilutions were prepared in sterile distilled water and the number of total viable bacteria was estimated using the pour plate technique and nutrient agar. This is a non-selective growth medium for bacteria which is suitable for comparative purposes.

Additional tests were carried out to estimate the number of coliform bacteria and *Escherichia coli* using MacConkey Agar. This is a differential medium for the detection, isolation and enumeration of coliforms and intestinal pathogens in water, dairy products and biological specimens. Serial dilutions and the pour plate technique were used for this method. There were consistently 10^5 to 10^7 coliforms in the samples, but our interest was in the specific indicator organism and therefore results are presented for *E. coli* only.

The pH, temperature, electrical conductivity and percentage dissolved oxygen were measured in selected compost teas used in Trials 3 and 4a. Appropriate probes were immersed in the brewing vessel immediately following brewing and prior to application. Measurements were made three times and mean values were recorded.

Nutrient analyses were performed on selected compost teas from the nursery trials (Trial 6). Compost tea samples were analysed for soluble nitrogen (ammonium and nitrate) and phosphorus using standard colourimetric methods, and for all other elements using induction coupled plasma analysis (ICP). The chemical analyses required pre-analysis filtration (0.45 µm filter) as the samples could have contained suspended material that would have interfered with the analytical equipment and acidification to maintain the elements in solution. The pH of the samples was also measured. All data therefore refer to concentrations in solution.

Nutrient analyses were performed on samples of all composts used to make teas in Trials 1, 2, 3, 4 and 6. Composts were analysed for major and minor nutrients, salt concentrations (cF), pH and carbon dioxide evolution, which is a measure of compost stability. Composts were tested for the following parameters:

- Physico-chemical parameters
    - bulk density
    - dry matter
    - pH
    - electrical Conductivity (eC)
- Chemical parameters
    - Water extractable
        - Chloride
        - Nitrate-N (NO_3-N), Ammonium-N (NH_4-N), Total N
        - phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), sodium (Na), boron (B), copper (Cu), iron (Fe), molybdenum (Mo), zinc (Zn) and manganese (Mn)
        - Total C, Total P, Total K
- Biological parameters
    - Carbon dioxide (CO_2) evolution

Additional parameters were determined by calculation:

- Moisture Content
- C:N ratio
- Nitrate-N:Ammonium-N ratio
- Volatile Solids Content

The methods used for testing composts are listed in Appendix I.

Results

The results from microbial analysis of compost teas from Trials 1 and 2 were published along with the rest of results from these trials in the Annual Report (2004). Microorganisms were counted in two brews taken from Trial 6 (Notcutts, 06.07.05 and 26.07.05) (Table 2).

Table 2. Number of microorganisms in brews (Trial 6)

Nursery	Brew date	Mean colony forming units (CFU)/ml*	
		Nutrient agar	MacConkey agar (*E. coli*)
Notcutts	06.07.05	2.67×10^8	<1000
Notcutts	26.07.05	2.93×10^8	<1000

*Stated values were the means of two counts

There were less than 1000 colony forming units (CFU) of *E. coli*/ml of compost tea in both brews tested, and just under 3×10^8 CFU of microorganisms/ml of tea in the brews tested.

The pH of all compost teas used in Trials 3 and 4 lay between 7.1 and 7.4 (Table 3). The teas were brewed at ambient glasshouse temperature and their temperatures followed closely those within the glasshouse (data not shown). Tea temperature varied between around 16 and 20^{o}C. The salt content (cF) of compost teas varied between 935 and 1218 µS cm^{-1}. The dissolved oxygen content varied between 8.1 and 9.0 ppm.

Table 3. The pH, temperature, electrical conductivity (cF or salt content) and percentage dissolved oxygen recorded in compost teas used in Trials 3 and 4a

Compost tea	pH	Temperature ^{o}C	cF (µS/cm)	Dissolved oxygen (ppm)
Trial 3 (Tr. 3, van Iersel, 21.09.04)	7.2	20.2	1104	8.6
Trial 3 (Tr. 3, van Iersel, 19.10.04)	7.3	18.9	1165	8.2
Trial 3 (Tr. 3, van Iersel, 16.11.04)	7.4	17.6	1197	8.2
Trial 3 (Tr. 3, van Iersel, 14.12.04)	7.2	16.8	1136	8.4
Trial 4a (Tr. 3, van Iersel, 18.10.04)	7.3	18.3	935	8.1
Trial 4a (Tr. 3, van Iersel, 01.11.04)	7.2	16.5	1218	8.8
Trial 4a (Tr. 3, van Iersel, 15.11.04)	7.1	17.6	989	8.6
Trial 4a (Tr. 3, van Iersel, 29.11.04)	7.3	16.3	1046	9.0

The pH values of the tea samples taken from Trial 6 (Nursery Trials) were neutral/slightly alkaline (Table 4). There were low levels of nitrate and ammonium (i.e. below detection limit). There were low levels of other major nutrients and trace elements in the compost teas tested.

The physical, chemical and biological characteristics of composts used to make teas in Trials 1, 2, 3, 4 and 6 are shown in Table 5. The values obtained for parameters tested show that composts used to make teas were generally of good quality. The pH values lay between 7.2 and 7.9, the salt concentrations (eC) between 459 and 1650 µS/cm, the bulk density lay between 400 and 760 g/l and the dry matter content between 43.0 and 74.7%. The C:N ratios were generally 12 or 13:1, with three composts between 15 and 17:1. Concentrations of plant available nutrients were appropriate for greenwaste composts and all of the composts were considered sufficiently stable according to the British Standards Institution Publicly Available Specification 100:2005 (PAS 100:2005).

Table 4. Nutritional composition of compost teas used in nursery trials (Trial 6)

Nursery	pH	NH_4-N	NO_3-N	P	K	S	Ca	Mg	Fe	Cu	B	Zn
Hewton[a]	7.2	<1	<1	5.1	237	19	49	0.5	3.0	0.1	0.1	0.6
Aline F.[b]	7.2	<1	<1	5.1	237	19	50	0.5	2.8	0.1	0.1	0.5
Notcutts[c]	7.7	<1	<1	0.3	312	51	70	15.0	2.1	0.2	0.2	0.1
Notcutts[d]	7.7	<1	<1	1.0	314	42	64	11.4	2.7	0.0	0.2	0.1

[a]Tea from Hewton nursery brewed on 18.08.05; [b]Tea from Aline Fairweather brewed on 28.08.05; [a]Tea from Notcutts brewed on 11.09.05; [d]Tea from Notcutts brewed on 25.09.05;

The van Iersel composts (which are currently used to make almost all of the compost teas used in commercial UK nursery practice) were similar to one another apart from the sample supplied by Hewton Nurseries during Trial 6. It differed from the other van Iersel composts in terms of most of the parameters measured. For example, it had a higher salt content (eC), higher concentrations of total P and K, chloride, extractable P, K, Ca and Na. The van Iersel composts had higher bulk density values than the other composts used, but were otherwise similar to them.

The composts used in Trial 2 differed from the van Iersel composts in that they had lower bulk density and eC values. The compost used in Treatment 3, Trial 2 was based partly on animal manure and had a correspondingly high ammonium:nitrate ratio. Otherwise, the alternative composts used in Trial 2 were similar to the van Iersel composts.

The composts used in Trial 3 differed from the van Iersel composts in that they again had lower bulk density values. Only the very mature compost used in Treatment 6, Trial 3 had a lower eC value than typical van Iersel composts. The main difference between the compost used in Treatment 4, Trial 3 and the van Iersel composts was that the CO_2 evolution rate (a measure of compost stability/maturity) was considerably higher (at 11.3 mg CO_2/g volatile solids/day) than those measured in the van Iersel composts. The van Iersel composts had CO_2 evolution rates ranging between 2.2 and 6.7, but most were below 5.0 mg CO_2/g volatile solids/day.

Table 5. Characteristics of composts used to make compost teas

Sample Reference	As received basis: Bulk Density g/l	Dry Matter %	Moisture %	pH	eC µS/cm	Dry matter determinations: % C	% N	C:N	Total P mg/kg	Total K mg/kg	Water extractable (mg/kg dry matter): Chloride	NH_4-N	NO_3-N	Total Soluble N	NH_4:NO_3
Trial 1 (van lersel)	720	52.3	47.7	7.2	1137	12.9	1.1	12.1	1595	6784	1426	1.9	440.8	442.7	1:232
Trial 2 (van lersel) SAC	750	57.7	42.3	7.5	1010	14.9	1.1	13.1	1620	5865	1141	2.3	442.8	445.1	1:193
Trial 2 (CMC compost ii.)	406	74.7	25.3	7.7	765	16.3	1.2	13.1	2007	4287	1831	74.2	23.1	97.3	3:1
Trial 2 (greenwaste i)	400	66.0	34.0	7.9	459	18.7	1.1	17.1	1980	4869	1212	3.8	<1.0	3.8	n/a
Trial 2 (greenwaste ii)	447	63.3	36.8	7.8	749	22.8	1.5	15.1	2399	5488	2317	8.8	<1.0	8.8	n/a
Trial 3 (van lersel) SAC 3	700	58.2	41.8	7.4	1071	10.7	0.9	12.1	1578	5556	1163	2.5	612.6	615.1	1:245
Trial 3 (g'waste immature)	476	71.3	28.8	7.4	1320	14.8	1.0	15.1	2254	4835	2035	610.3	<1.0	610.3	n/a
Trial 3 (g'waste mature)	565	68.9	31.1	7.2	1610	13.5	1.1	13.1	2576	6230	2760	88.9	255.4	345.3	1:3
Trial 3 (g'waste v. mature)	569	51.8	48.2	7.4	587	25.2	2.1	12.1	2558	3355	356	5.1	629.6	634.7	1:123
Trial 4a (van lersel)	680	57.1	42.9	7.3	1456	12.1	1.0	12.1	1787	5902	1946	<1.0	620.8	620.8	n/a
Trial 4b (van lersel)	743	48.8	51.2	7.3	1202	14.9	1.2	12.1	1563	6718	1278	2.1	321.3	323.4	1:153
Trial 6 (Hewton, van lersel)	670	43.0	57.0	7.2	1650	23.7	1.8	13.1	2846	10833	2091	<1.0	1726.8	1726.9	n/a
Trial 6 (Hewton, van lersel)	760	58.1	41.9	7.5	1107	10.9	0.9	13.1	1605	5563	1119	<1.0	564.8	564.8	n/a
Trial 6 (Aline F., van lersel)	745	56.3	43.7	7.2	1068	14.7	1.2	12.1	1450	5427	1379	1.1	235.4	236.5	1:214
Trial 6 (West E., van lersel)	734	58.1	41.9	7.3	1326	12.9	1.0	13.1	1717	5582	1206	<1.0	578.3	578.3	n/a
Trial 6 (West E., van lersel)	707	52.8	47.2	7.4	1272	16.7	1.4	12.1	1268	5931	1171	1.7	435.2	436.9	1:256
Trial 6 (Notcutts, van lersel)	700	54.6	45.4	7.3	1010	12.5	1.0	13.1	1703	6484	1378	<1.0	451.5	451.1	n/a
Trial 6 (Notcutts, van lersel)	752	46.9	53.1	7.5	1115	15.3	1.3	12.1	1984	6260	1286	<1.0	686.5	686.5	n/a
Mean	**640**	**57.8**	**42.2**	**7.4**	**1106**	**15.8**	**1.2**	**13:1**	**1916**	**5887**	**1505**	**n/a**	**n/a**	**490.5**	**n/a**

Table 5 (continued). Characteristics of composts used to make compost teas

	Water extractable (mg/kg dry matter)												
Sample Reference	**P**	**K**	**Ca**	**Mg**	**S**	**Na**	**B**	**Cu**	**Fe**	**Mo**	**Zn**	**Mn**	**Respiration mg CO2/g VS/day**
Trial 1 (van lersel)	96	2598	428	179	401	480	1.9	<1	252	<1	1.2	2.1	3.6
Trial 2 (van lersel) SAC	74	2763	413	162	380	460	2.1	<1	454	<1	2.5	5.7	2.2
Trial 2 (CMC compost ii.)	67	2590	529	44	487	373	1.6	<1	237	<1	1.3	2.5	6.1
Trial 2 (greenwaste i)	76	2026	395	78	579	261	2.3	<1	449	<1	1.9	2.3	2.9
Trial 2 (greenwaste ii)	86	2741	549	103	523	631	2.8	<1	582	<1	4.6	4.0	4.9
Trial 3 (van lersel) SAC 3	77	2947	564	209	388	499	2.3	<1	510	<1	2.7	6.0	3.1
Trial 3 (g'waste immature)	152	3201	423	87	407	407	2.7	<1	94	<1	4.4	7.0	11.3
Trial 3 (g'waste mature)	89	4020	553	184	385	844	3.5	<1	103	<1	2.2	4.6	5.8
Trial 3 (g'waste v. mature)	71	2016	389	110	395	108	2.3	<1	272	<1	2.6	0.5	2.8
Trial 4a (van lersel)	73	2960	428	245	238	512	2.0	<1	348	<1	1.1	2.6	2.8
Trial 4b (van lersel)	120	2830	569	272	454	456	1.2	<1	18	<1	1.2	4.4	4.2
Trial 6 (Hewton, van lersel)	182	6300	689	283	521	854	1.1	<1	3	<1	<1	<1	4.2
Trial 6 (Hewton, van lersel)	42	2626	404	117	309	467	<1	<1	22	<1	<1	<1	4.3
Trial 6 (Aline F., van lersel)	58	3120	351	174	462	306	2.2	<1	90	<1	<1	<1	2.8
Trial 6 (West E., van lersel)	49	2656	377	239	395	384	1.0	<1	112	<1	<1	2.1	6.7
Trial 6 (West E., van lersel)	109	2104	429	270	412	459	<1	<1	107	<1	1.1	3.7	5.3
Trial 6 (Notcutts, van lersel)	66	2971	366	114	459	510	1.2	<1	73	<1	<1	<1	4.7
Trial 6 (Notcutts, van lersel)	89	2306	445	262	504	326	<1	<1	110	<1	1.8	4.1	4.9
Mean	**88**	**2932**	**461**	**174**	**428**	**463**	**1.8**	**<1**	**213**	**<1**	**1.7**	**3.0**	**3.1**

Discussion

A specific microbiological concern about compost tea production practices that use additives to increase microbial populations is that they may also support growth of bacterial human pathogens from undetectable to easily detectable numbers thereby potentially posing a risk of contaminating crop plants with human pathogens.

However, the evidence of dangers from pathogens is inconsistent. There have been no reported cases of food borne illness from the use of compost tea but, on the other hand, there have been no epidemiological health/microbial studies done to evaluate this effect. For compost tea, averting the theoretical possibility of contaminating crops with human pathogens can be approached by:

(a) implementing measures that reduce the potential for pathogens to enter compost tea production systems, and
(b) performing quality assurance tests to demonstrate that specific compost tea production systems produce compost tea that meets microbiological quality guidelines.

In general, pathogens that enter the composting process in feedstocks might come out at the same, lower, or higher levels. Processes or materials that have a high probability of increasing human pathogens during compost tea production are of greatest concern. Feedstocks such as manure have a high probability of containing pathogenic organisms. These types of materials can be processed to reduce populations of indicator microbes and pathogens to acceptable levels by following the requirements of PAS 100:2005.

Compost stability affects the ability of *Salmonella* spp. to re-colonise composted materials (Milner *et al*, 1987) but data are lacking on the relationship between human pathogen growth potential in compost tea and compost stability. Re-growth of human pathogens in compost tea appears to be dependent on the concentration of compost tea additive used. In addition, the significant interaction between compost source and additives on the re-growth potential of human pathogens indicates a need to test individual batches of compost with defined concentrations of compost tea.

The recent US National Organic Standards Board Compost Tea Task Force Report (NOSB, 2004) proposed that compost tea made **without compost tea additives** could be applied without restriction. Compost tea made **with compost tea additives** could be applied without restriction if the compost tea production system (same compost batch, additives, and equipment) has been pre-tested to produce compost tea that meets the recommended recreational water quality guidelines for a bacterial indicator of fecal contamination (*E. coli* or enterococci). It was further proposed that if compost tea made with compost tea additives has not been pre-tested for indicator bacteria, its use on food crops should be restricted to the

90/120 day pre-harvest interval. Crops not intended for human consumption, such as ornamental plants should be exempt from bacterial testing and 90/120 day pre-harvest interval restrictions.

Our results are encouraging in that they show that the populations of the indicator *E. coli* bacteria are consistently <1000 CFU ml^{-1}, a value which falls within the acceptable range of values recommended in PAS 100:2005. This indicates that this is unlikely to be a risk from human pathogens in the compost teas used in this project.

The chemical properties of the compost teas used in Trials 3 and 4a were similar to those recorded on compost teas in recent American studies (Scheuerell and Mahaffee (2004)). The pH of all compost teas used in Trials 3 and 4 lay between 7.1 and 7.4 and was a reflection of the pH of the water used as well as the composts used in the trials. The compost teas used in these recent studies caused no damage to cucumber seedlings and many of them were associated with suppression of *Pythium ultimum* in container-grown plants. It is therefore unlikely that the chemical properties of compost teas used in Trials 3 and 4a would cause plant damage. (There was no evidence of plant damage caused by compost teas in Trials 3 or 4.)

The pH of the tea samples used in Trial 6 was neutral/slightly alkaline, reflecting the pH of the compost from which the tea was derived. Surprisingly there was no detectable mineral N in these tea samples. In young compost there is likely to be low levels of mineral N due to immobilisation by the microbial biomass, but as the compost matures, a supply of ammonium is expected which is oxidised to nitrate as the maturation process proceeds. It is possible that during the tea brewing process ammonia is lost *via* volatilisation at the slightly alkaline pH and that the conditions are favourable for denitrification (loss of nitrate *via* microbial reduction). This would be more likely to occur in non-aerated teas rather than the aerated tea used here, but the addition of molasses would increase the likelihood of denitrification occurring.

The teas otherwise contained a good supply of macronutrients (P, S, K, Ca and Mg) and micronutrients (Fe, Cu B and Zn). The supply of each of these elements either singly or in combination (synergistic effects) could play a role in the beneficial effects of compost teas on plant growth and development including disease resistance. The use of foliar sprays provides an efficient mechanism for overcoming specific nutrient deficiencies and many products both synthetic and natural are available with a range of formulations designed for specific crops. Similar benefits could be expected from the application of these teas as a soil drench.

The trace elements in the teas analysed here will be less soluble at the slightly alkaline pH than at a lower, more acidic pH. The exception to this is molybdenum, which becomes more soluble at higher pH; however the concentration of this element was below the detection limit of the ICP which indicates that its concentration was insignificant. The solubility of elements such as Fe is likely to be enhanced in the organic matrix of the tea that will include molecules which can serve as complexing and chelating agents.

The composts used to make the compost teas in this work were all based on greenwaste, with the exception of that in Treatment 4, Trial 2 (which was based on a mixture of strawy cattle manure, greenwaste and grass clippings. They were all high quality composts which would pass the criteria required to conform with (PAS 100:2005) for composts. PAS 100:2005 specifies limit values for a range of parameters. Compost producers and their composting processes must be accredited and composts must be tested to ensure that the values of all specified parameters lie within the limit levels before any compost can be sold in the UK as having achieved PAS100:2005.

The pH values, salt concentrations, physical parameters and C:N ratios obtained were acceptable for composted products. Concentrations of plant available nutrients were appropriate for greenwaste composts and all of the composts were considered sufficiently stable according to the British Standards Institution Publicly Available Specification 100:2005 (PAS 100:2005).

The fact that the van Iersel composts tended to have higher bulk density values than the other composts used suggests that there may be soil or clay particles added prior to or following the composting process. This is a common practice in CMC composting systems and is thought to improve the composting process and/or aid colonisation of the compost by beneficial microorganisms during maturation (C. Leifert, personal communication).

The main difference between the compost used in Treatment 4, Trial 3 and the van Iersel composts was that the CO_2 evolution rate (a measure of compost stability/maturity) was considerably higher than those measured in the van Iersel composts. This was to be expected, since the composts in Trial 3 were specially selected to be of different ages. The youngest (least stable) compost had the highest CO_2 evolution rate, and the oldest (most stable/mature compost had the highest CO_2 evolution rate, as expected. The van Iersel composts had CO_2 evolution rates ranging between 2.2 and 6.7 mg CO_2/g volatile solids/day, but most were below 5.0. This indicates that the van Iersel composts used tended to be stable and very mature.

TRIAL 6 - Nursery-based trials to determine the effects of compost teas

Introduction

The aim of this project as a whole was to develop methods for using compost teas, which can be easily used on commercial nurseries. Information gained during Objectives 1 to 4 was used to design trials, which were carried out on four nurseries throughout the UK. The intention was to assess the use of compost teas as part of an integrated pest and disease control programme on commercial nurseries. For this reason, the impact of teas on existing IPM programmes was assessed at one of the four nurseries (Notcutts) during the summer of 2005.

Materials and methods

Trials were set up at the following four nurseries:

Hewton Nursery
Bere Alston
Yelverton
Devon
PL20 7BW

Aline Fairweather
Hilltop Nursery
Beaulieu
Hants
SO42 7YR

West-end Nurseries
Moles Lane
Marldon
Paignton
Devon
T3 1SY

Notcutts Nurseries
Newbourne
Woodbridge
Suffolk
IP12 4AF

There were three treatments and four replicates in each trial, with twenty plants of each species per plot. Some of these trials involved lavender and choisya in order to provide continuity from Trials 1 to 4. However, some growers have included additional crops, which are important to their businesses.

Plants used were as follows:

- Choisya [*Choisya ternata* 'Aztec pearl'], 16 week-old plugs (3 cm diameter) potted into 9 cm liner pots (Hewton Nursery)
- Cordyline [*Cordyline australis*], 18 week-old plugs (3 cm diameter) potted into 9 cm liner pots (Hewton Nursery)
- Cordyline [*Cordyline australis* 'Torbay red'], 12 week-old plugs (3 cm diameter) potted into 9 cm liner pots (West End Nurseries)
- Lavender [*Lavandula angustifolia* 'Willowbridge calico'], 16 week-old plugs (3 cm diameter) potted into 9 cm liner pots (West End nurseries)
- Lavender [*Lavandula angustifolia* 'Violet lace'], 16 week-old plugs (2.5 cm diameter) potted into 9 cm liner pots (Aline Fairweather)

- Phygelius [*Phygelius* 'Orange fanfare'], 10 week-old plugs (2.5 cm diameter) potted into 9 cm liner pots (Aline Fairweather)
- County rose [*Rosa* 'Oxfordshire'], 9 month-old plugs (5 cm diameter) potted into 1 litre (Notcutts nurseries)

Treatments were as follows:

- Tr. 1 Plain water applied at same rates as compost teas
- Tr. 2 Compost tea applied at 5 ml/m^2 (i.e. 50 l/ha). This may have been diluted in water in order to allow application through overhead irrigation equipment, but the tea was still applied at the same rate. Tea was made according to the methods noted below.
- Tr. 3 Standard fungicide treatment [as normally or formerly applied on the nursery, see Appendix II for details]

Methods

- Growing media was mixed as normal for each nursery and plugs/liners were potted on into the pots to be used during the trial (i.e. 240 plants of each of choisya, lavender, cordyline, phygelius or rose).
- Twenty plants of the same species were placed in each carrying tray. One tray of each made up a plot. Trays were not essential, they simply made it easier to remove the plants for treatment.
- Each tray was labelled clearly (indelible pen) with the treatment and replicate
- The trays were placed in a (specified) randomised block design on the floor of the glasshouse
- Each trial block of species was surrounded with other plants of the same species to minimise edge effects.
- Compost teas were prepared using the van Iersel Xtractor and were applied fortnightly (or plain water control for Treatment 1) starting on the day of potting, as coarse overhead sprays at 5 ml/m^2 (i.e. 50 l/ha). The tea may have been diluted in water in order to allow application through overhead irrigation equipment, but the tea will still have been applied at the same rate.
- Compost tea treatments were sometimes omitted during the months of December, January and February if growing media became too wet. Exact records were kept as to the dates when tea was applied (Appendix II).
- Fungicides were applied according to normal commercial practice to plants in Treatment 3 (details of rates and application dates for each nursery are in Appendix II).
- Trays were removed and placed in a different area in order to apply treatments. They were replaced in the randomised block design after treatment. This was to avoid cross contamination of adjoining treatments.
- Details of trial set up, assessment dates and other relevant details are listed in Appendix II.

Assessments

- Plant growth and health were assessed on the following dates after potting/start of trial:
    - approximately 4, 7, 9 and 12 months (Hewton)
    - approximately 2, 5, 8 and 9 months (Aline Fairweather)
    - approximately 4, 7, 10 and 12 months (West End Nurseries)
    - approximately 4, 7, 10 and 12 months (Notcutts)
- The following were recorded:
    - plant height measured (mm)
    - number of breaks or shoots (selected assessments)
    - root development
    - quality
- The assessment scale used for plant quality was the same as that used in Trials 3 and 4.
- Plants were checked weekly for incidence of pests and diseases. If pests/diseases were present, the severity of the pest or disease attack was quantified using 0 – 5 scoring systems similar to those used in Trials 3 and 4.

Results for Hewton Nurseries Trials

***Choisya* 'Aztec Pearl' (Hewton)**

First, second and third assessments (4, 8 and 10 months after potting)

There were no significant differences between treatments in terms of plant height or number of breaks in choisya plants at the first three assessments made. There were low levels of pest, disease and weed incidence on the plants throughout the trial, but no significant differences in the incidence of pests and diseases between treatments. The primary cause of pest damage was light brown apple moth caterpillars (*Epiphyas postvittana*).

Final assessment (12 months after potting)

Choisya plants treated with compost tea were significantly shorter (p=0.05) than those treated with plain water (control) or the standard fungicide programme at the final assessment (Table 6, Figure 9). There was no significant difference (p=0.05) in the height of plants treated with fungicide compared to the control treatment.

Table 6: Effect of compost tea and fungicide on the mean height, number of breaks, root score and quality score of *Choisya* 'Aztec Pearl' plants on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries)

Treatment	Plant height (mm)	No. of breaks	Root score	Quality score
1. Water	215	6.3	3.9	3.6
2. Compost tea	212	6.4	3.7	3.7
3. Fungicides	217	6.1	3.6	3.4
Mean	214	6.3	3.7	3.6
LSD	**18**	**0.8**	**0.6**	**0.4**

Root score: 0 = no visible roots when pot was removed, 5 = large numbers of roots visible
Quality score: 0 = Dead or poor plant, 5 = Very high quality plant

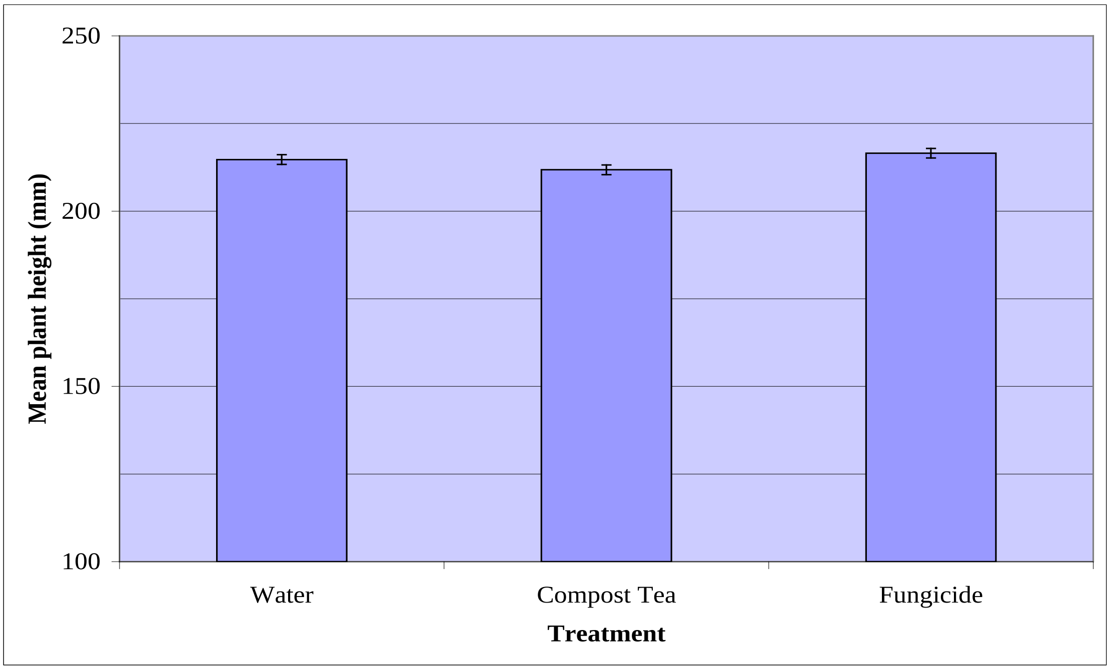

Figure 9. Effect of compost tea and fungicide on plant height (mm) of *Choisya* 'Aztec Pearl' on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries) **.** Error bars represent standard error of the mean (SEM).

There was no significant difference (p=0.05) in the number of breaks in choisya plants between the three treatments (Table 6).

Choisya plants treated with compost tea or fungicides had significantly poorer (p=0.05) root and quality scores than those in the control treatment (1, Table 6, Figure 10). There were no significant differences (p=0.05) between root scores on plants treated with compost tea or fungicides. Similarly, there were no significant differences (p=0.05) between quality scores of plants treated with either plain water or compost tea.

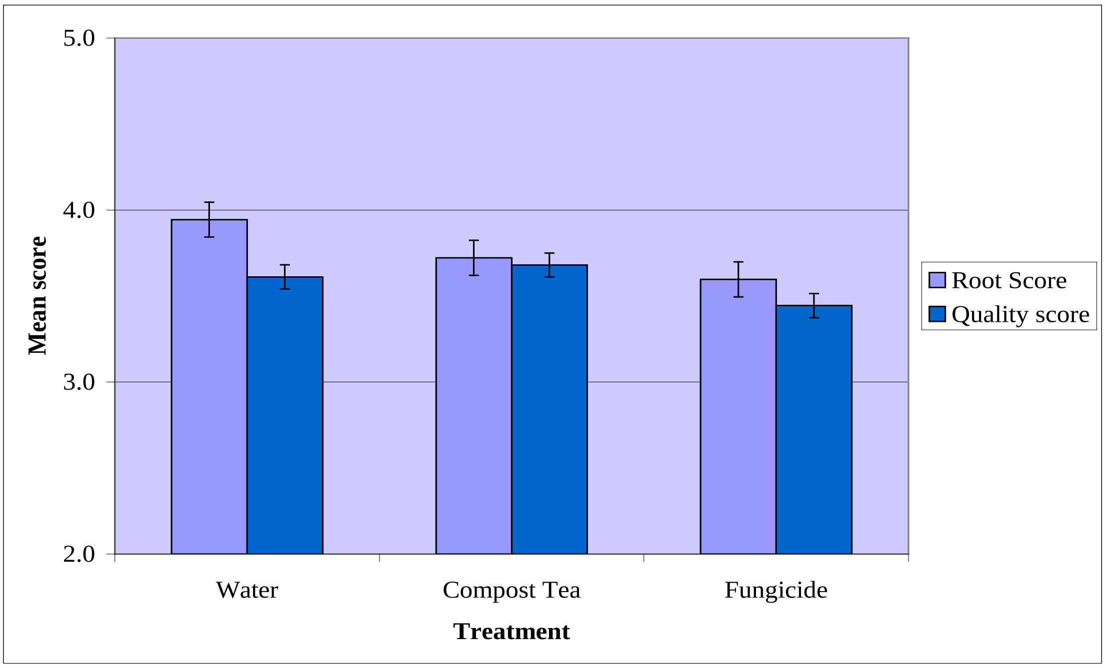

Figure 10. Effect of compost tea and fungicide on mean root and quality scores of *Choisya* 'Aztec Pearl' on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries). Error bars represent standard error of the mean (SEM).

There was no disease recorded in the trial (Table 7). There was a moderate level of pest damage throughout the choisya plants, but there were no significant differences in the amount of pest damage between treatments. The primary cause of damage was from caterpillar feeding, which was seen across the treatments. A moderate number of active light brown apple moth larvae were seen. Other pests noted (either through damage or the presence of active pests) were thrips (*Thysanoptera sp*), slugs (*Mollusca sp*.) and snails (*Mollusca sp*.).

There was also a low level of weed incidence (Table 7, Figure 11). Plants treated with compost tea had significantly more weeds (p=0.05) than those treated with plain water (control) or fungicide. There was no significant difference (p=0.05) between weed scores recorded on plants treated with plain water or fungicide. The main weeds found in all treatments were moss and liverwort, although pearlwort (*Sagina subulata*) and ferns were also found.

Table 7. Effect of compost tea and fungicide on the mean incidence of botrytis, leaf spot, dieback, pest score and weeds on *Choisya* 'Aztec Pearl' plants on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries)

Treatment	Botrytis score	Leaf spot score	Dieback score	Pest score	Weed score
1. Water	5.0	5.0	5.0	4.2	4.9
2. Compost tea	5.0	5.0	5.0	4.1	4.6
3. Fungicides	5.0	5.0	5.0	4.2	4.8
Mean	5.0	5.0	5.0	4.2	4.8
LSD	**0.0**	**0.0**	**0.0**	**0.1**	**0.2**

Score: 0 = Dead or high incidence , 5 = No disease or pest (or damage from) observed

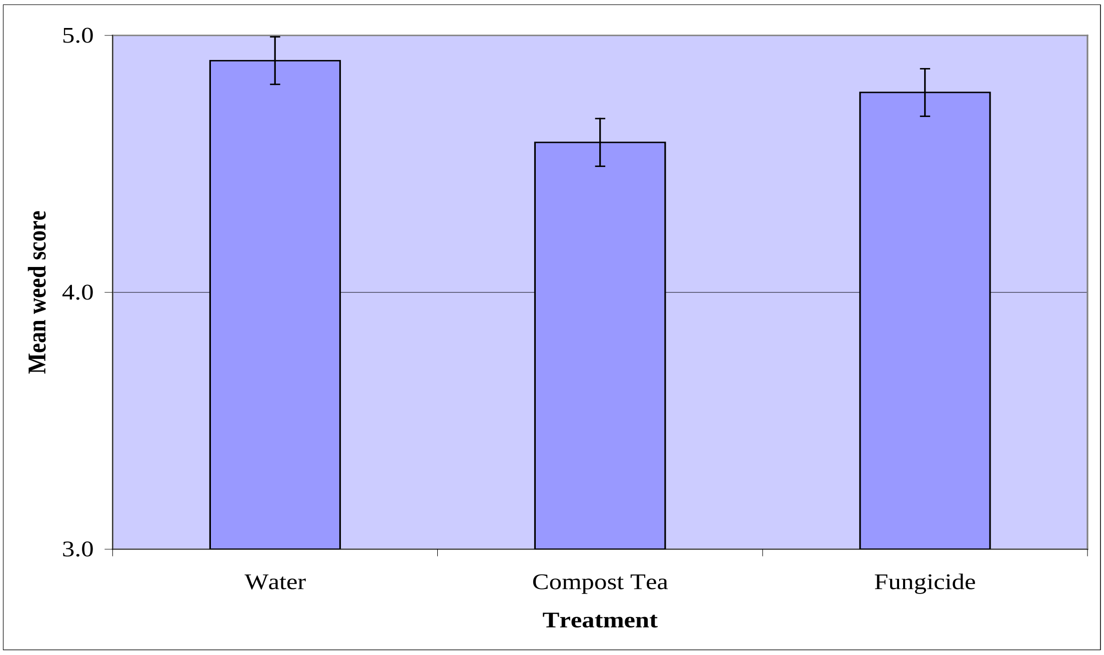

Figure 11. Effect of compost tea and fungicide on mean weed score in pots of *Choisya* 'Aztec Pearl' on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries). Error bars represent standard error of the mean (SEM).

***Cordyline australis* (Hewton)**

First, second and third assessments (4, 7 and 9 months after potting)

During the first two assessments the cordyline plants treated with compost tea or fungicide were significantly shorter than those treated with plain water. It wasn't until the third assessment in May that plants treated with compost tea or fungicide that were found to be significantly taller than the controls (see Appendix II for details of assessment dates).

Cordyline plants treated with compost tea had the same root scores or higher root scores than the control in the first three assessments.

At the first two assessments, cordyline plants treated with compost tea had significantly poorer quality scores than those in the control treatment. However, at the third assessment, plants treated with compost tea had significantly greater root scores than the control.

Plants treated with fungicide had poorer quality scores than the control plants in all assessments.

There were no significant differences in disease or weed incidence between the treatments in any of the first three assessments.

Final Assessment (12 months after potting)

Cordyline plants treated with compost tea or fungicide were significantly taller (p=0.05) than plants treated with plain water (Table 8, Figure 12). There were no significant differences (p=0.05) between plants treated with compost tea and fungicide.

Table 8. Effect of compost tea and fungicide on the mean height, root score and quality score of *C. australis* plants on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries)

Treatment	Plant height (mm)	Root score	Quality score
1. Water	643	3.8	4.0
2. Compost tea	674	4.6	4.4
3. Fungicides	671	3.8	4.2
Mean	663	4.1	4.2
LSD	**30**	**0.5**	**0.3**

Root score: 0 = no visible roots when pot was removed, 5 = large numbers of roots visible
Quality score: 0 = Dead or poor plant, 5 = Very high quality plant

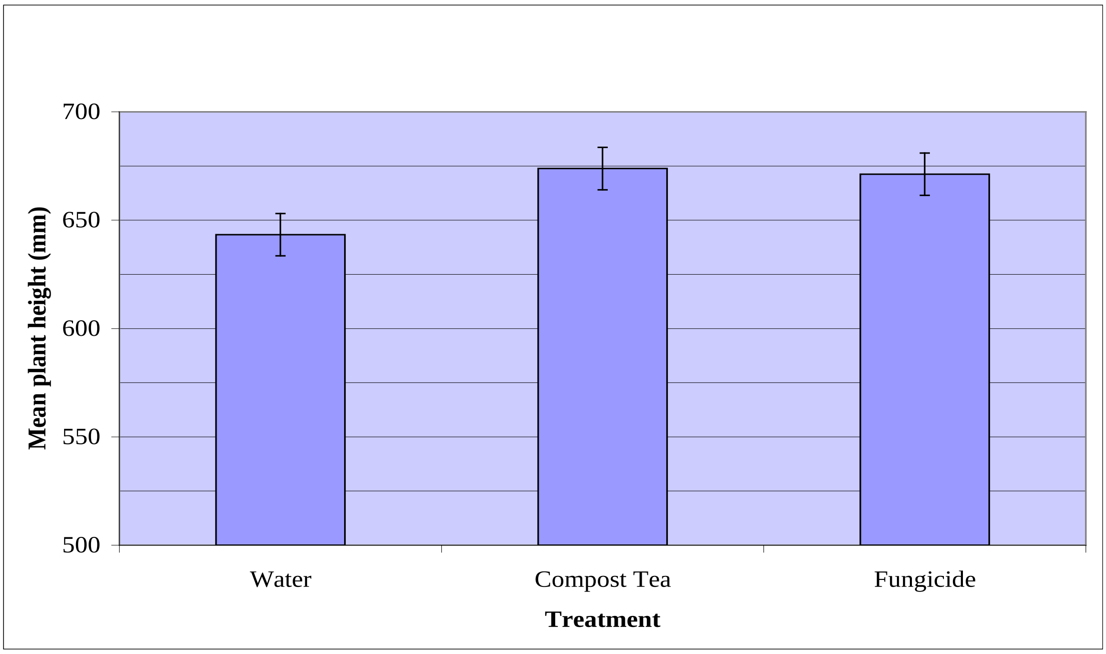

Figure 12. Effect of compost tea and fungicide on mean plant height (mm) of *C. australis* plants on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries). Error bars represent standard error of the mean (SEM).

Cordyline plants treated with compost tea had significantly greater root and quality scores (p=0.05) than those treated with plain water (control) or fungicide (Table 8, Figure 13). There was no significant difference (p=0.05) between the root scores recorded on plants treated with plain water or fungicide. Similarly, there was no significant difference (p=0.05) between the quality scores recorded on plants treated with plain water or fungicide.

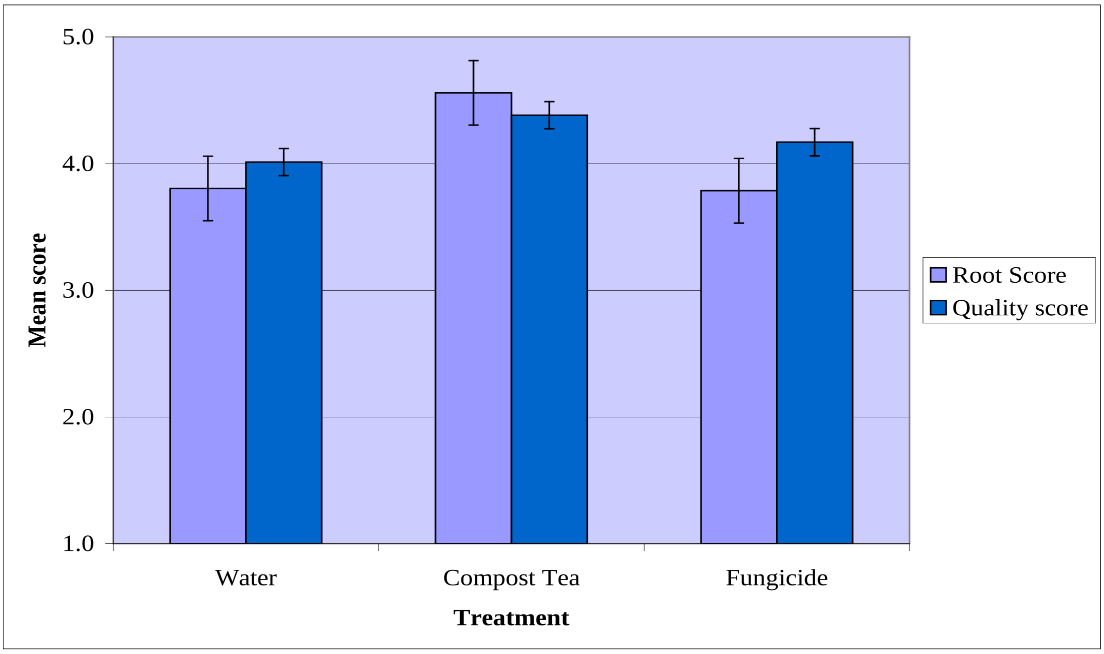

Figure 13. Effect of compost tea and fungicide on mean root and quality scores of *C. australis* plants on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries). Error bars represent standard error of the mean (SEM).

There were no diseases and no weeds present in the trial (Table 9). There was a low level of pest damage throughout the trial at the final assessment (Figure 14). Plants treated with compost tea or fungicide had significantly fewer incidences of pest damage (p=0.05) than the control treatment. The primary cause of pest damage was due to caterpillar, slug and snail feeding, which was seen across all three treatments. Moderate numbers of active light brown apple moth larvae, slugs and snails were seen. Feeding damage from vine weevil (*Otiorhynchus sulcatus*) and mammals (probably mice) was also seen, although active pests were not seen. Low levels of moss and liverwort were found on the plants, but there was no significant difference in incidence of these weeds between treatments.

Table 9. Effect of compost tea and fungicide on the mean incidence of botrytis, leaf spot, dieback, pests and weeds on *C. australis* plants on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries)

Treatment	Botrytis Score	Leaf spot score	Dieback score	Pest score	Weed score
1. Water	5.0	5.0	5.0	4.6	5.0
2. Compost tea	5.0	5.0	5.0	4.8	5.0
3. Fungicides	5.0	5.0	5.0	4.8	5.0
Mean	5.0	5.0	5.0	4.7	5.0
LSD	0.0	0.0	0.0	0.1	0.0

Score: 0 = Dead or high incidence , 5 = No disease or pest (or damage from) observed

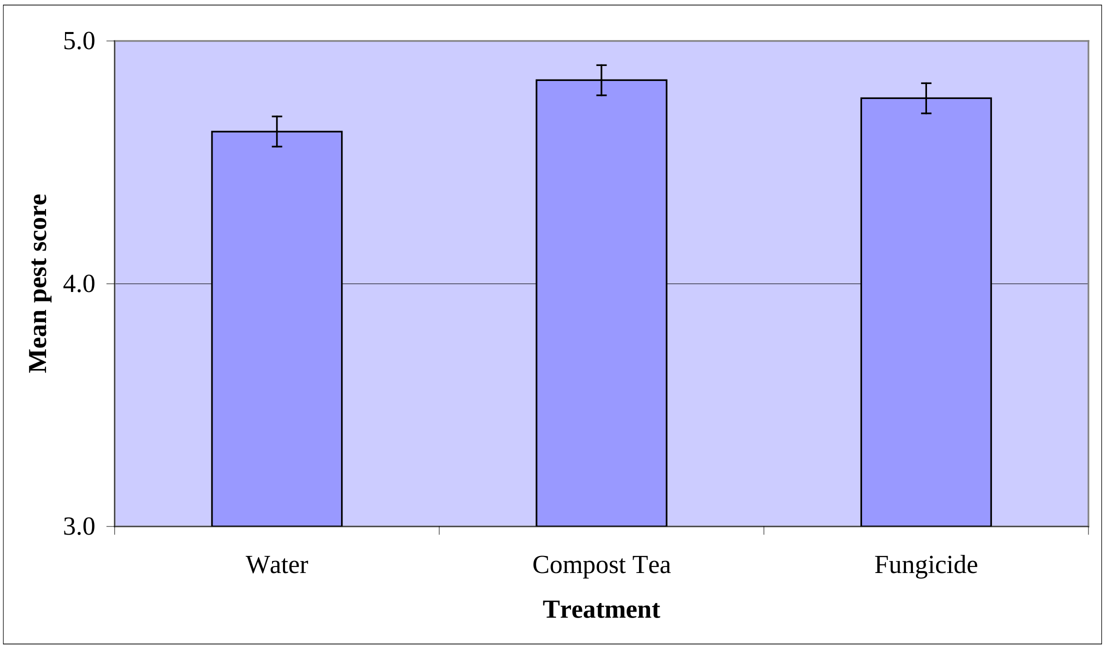

Figure 14. Effect of compost tea and fungicide on mean pest score of *C. australis* plants on 1st August 2005, 12 months after potting (Trial 6, Hewton Nurseries). Error bars represent standard error of the mean (SEM).

Discussion (Hewton Nurseries trials)

***Choisya 'Aztec Pearl'* (Hewton)**

Choisya plants treated with compost tea were significantly shorter than those in other treatments at the final assessment. The plants were trimmed twice, in February and May, which may have had an impact on the final height and number of breaks of the plants, although all treatments were treated equally.

Choisya plants treated with compost tea had significantly poorer root scores than plants treated with the plain water control. When the plants were assessed it was observed that the root systems of plants treated with compost tea were very wet, which may have been the result of excess water from compost tea applications and irrigation.

At the final assessment, choisya plants treated with compost tea or fungicide had significantly poorer quality scores than control plants. The deterioration in quality scores of these plants may again have been due to the presence of excess water in the pots.

At the final assessment, plants treated with compost tea were found to contain a significantly greater incidence of weeds and the main weeds found were moss and liverwort. As plants at this site were irrigated from overhead it is likely the moist compost surface, combined with the nutrients supplied by the compost tea were the cause of the higher weed incidence.

***Cordyline australis* (Hewton)**

At the final assessment, cordyline plants treated with compost tea or fungicide were significantly taller than those treated with plain water. During the first two assessments, cordyline plants treated with compost tea or fungicide were significantly shorter than those treated with plain water. It wasn't until the third assessment in June that the plants were found to be significantly taller. This indicates that the compost tea treatment had improved the long-term growth of the plants, although a similar trend was found with the standard pesticide treatment.

Cordyline plants treated with compost tea had consistently greater, or the same, root scores as the control at all four assessments, whilst plants treated with fungicide consistently had scores which were not significantly different from the control treatment. When the roots of the plants in the trial were inspected, plants treated with compost tea had more highly-branched, dense white root systems than those in other treatments and they showed less root death.

Plants treated with compost tea had significantly greater quality scores than control plants at the final assessment. This shows a similar trend to the results obtained for plant height assessments, again indicating that compost tea had improved the long-term growth of the plants. Plants treated with fungicide had poorer quality scores than the control plants in all four assessments, which indicates that the fungicide programme used adversely affected plant quality in this trial.

Results for Aline Fairweather Trial

Lavandula **'Violet lace' (Aline Fairweather)**

First, second and third assessments (2, 5 and 8 months after potting)

At the first assessment, lavender plants treated with compost tea were significantly taller than those treated with plain water. There was no significant difference in plant height between treatments at the following two assessments.

At the first assessment, lavender plants treated with compost tea had significantly greater root scores than those treated with plain water. At the following two assessments, there were no significant differences in root scores between treatments.

At the first two assessments, lavender plants treated with compost tea were not significantly different from those in the other two treatments in terms of plant quality. However, at the following assessment they had greater quality scores than those treated with plain water.

There were no significant differences in disease, pest or weed incidence between lavender plants in the three treatments at any of the first three assessment dates.

Final Assessments (9 months after potting)

Lavender plants treated with compost tea were significantly taller ($p=0.05$) than plants treated with plain water (control) or fungicide (Table 10, Figure 15). There was no significant difference between the heights of plants treated with water or fungicide. The mean number of breaks was not recorded at the final assessment.

Table 10. Effect of compost tea and fungicide on the mean height, root score and quality score of *Lavandula* 'Violet lace' plants at 29th July 2005, 9 months after potting (Trial 6, Aline Fairweather)

Treatment	Plant height (mm)	Root score	Quality score
Water	362	3.7	3.3
Compost tea	371	4.4	4.0
Fungicides	357	3.5	3.6
Mean	363	3.9	3.7
LSD	**25**	**0.5**	**0.4**

Root score: 0 = no visible roots when pot was removed, 5 = large numbers of roots visible
Quality score: 0 = Dead or poor plant, 5 = Very high quality plant

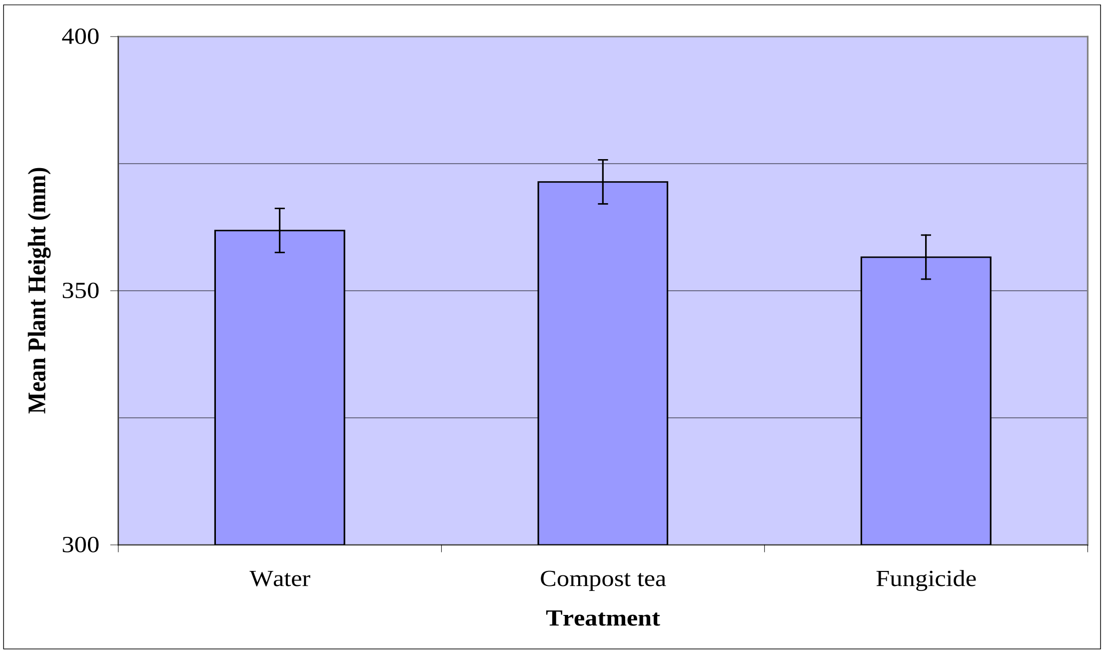

Figure 15. Effect of compost tea and fungicide on mean plant height (mm) of *Lavandula* 'Violet lace' plants at 29th July 2005, 9 months after potting (Trial 6, Aline Fairweather). Error bars represent standard error of the mean (SEM).

Lavender plants treated with compost tea had significantly greater root and quality scores (p=0.05) than those treated with plain water or fungicide (Table 10, Figure 16). There was no significant difference (p=0.05) in the root scores recorded on plants treated with plain water or fungicide. Similarly, there was no significant difference (p=0.05) in the quality scores recorded on plants treated with plain water or fungicide.

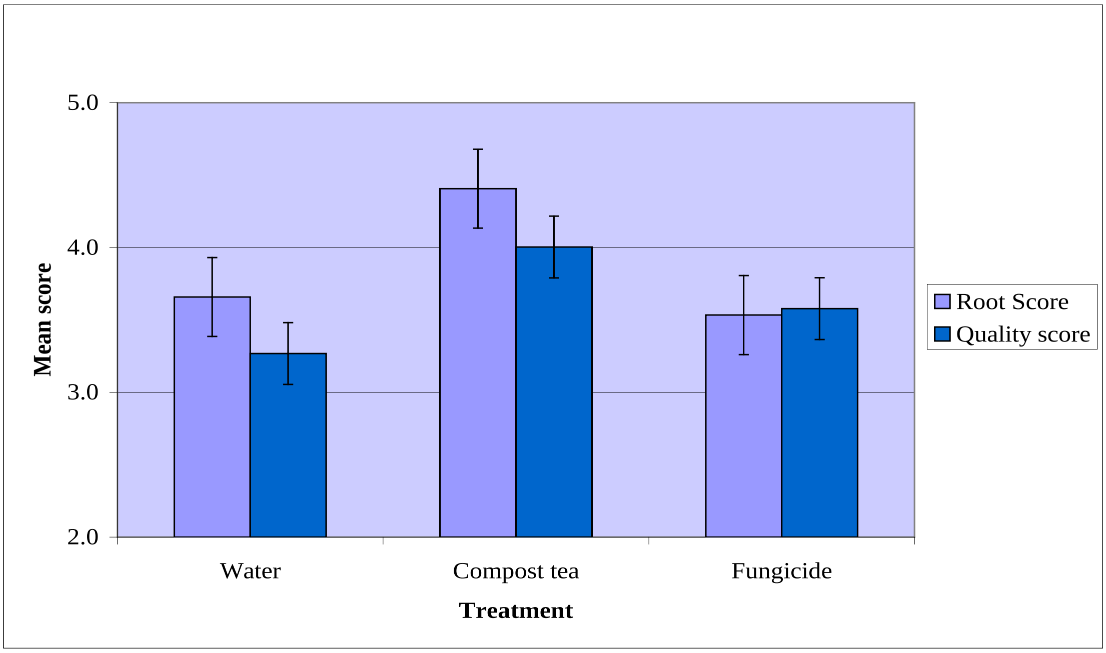

Figure 16. Effect of compost tea and fungicide on mean root and quality score of *Lavandula* 'Violet lace' plants, 9 months after potting on 29th July 2005 (Trial 6, Aline Fairweather). Error bars represent standard error of the mean (SEM).

There were no diseases and no weeds in the trial (Table 11). There was a low level of caterpillar damage on the lavender plants, although there was no significant difference in incidence of damage between treatments. Damage from caterpillar feeding was evident, and small numbers of active carnation tortrix moth were also seen.

Table 11. Effect of compost tea and fungicide on the mean incidence of botrytis, leaf spot, dieback pests and weeds on *Lavandula* 'Violet lace' plants, 9 months after potting on 29th July 2005 (Trial 6, Aline Fairweather)

Treatment	**Botrytis score**	**Leaf spot score**	**Dieback score**	**Pest score**	**Weed score**
Water	5.0	5.0	5.0	4.9	5.0
Compost tea	5.0	5.0	5.0	4.9	5.0
Fungicides	5.0	5.0	5.0	4.9	5.0
Mean	5.0	5.0	5.0	4.9	5.0
LSD	**0**	**0**	**0**	**0.1**	**0**

Score: 0 = Dead or high incidence , 5 = No disease or pest (or damage from) observed

Phygelius 'Orange Fanfare' (Aline Fairweather)

First, second and third assessments (2, 5 and 8 months after potting)

Phygelius plants treated with compost tea were significantly shorter at the third assessment, significantly taller at the second whilst there were no differences between treatments on the first assessment.

Phygelius plants treated with compost tea had a significantly greater number of breaks than those treated with water or fungicide at all of the assessment dates

At all assessment dates phygelius plants treated with compost tea had significantly greater quality scores than those treated with plain water, whilst plants treated with fungicide had the same quality scores as the control.

No significant differences in disease, pest or weed incidence were recorded between the treatments at any of the first three assessments.

Final Assessments (9 months after potting)

Phygelius plants treated with compost tea or plain water were significantly taller (p=0.05) than those treated with fungicide (Table 12, Figure 17).

Table 12. Effect of compost tea and fungicide on the mean height, number of breaks, root score and quality score of *Phygelius* 'Orange Fanfare' plants on 29th July 2005, 9 months after potting (Trial 6, Aline Fairweather)

Treatment	**Plant height (mm)**	**No. of breaks**	**Root score**	**Quality score**
Water	380	6.2	4.0	3.9
Compost tea	385	7.5	4.9	4.2
Fungicides	364	6.2	4.0	3.9
Mean	376	6.6	4.3	4.0
LSD	**26**	**0.9**	**0.6**	**0.3**

Root score: 0 = no visible roots when pot was removed, 5 = large numbers of roots visible
Quality score: 0 = Dead or poor plant, 5 = Very high quality plant

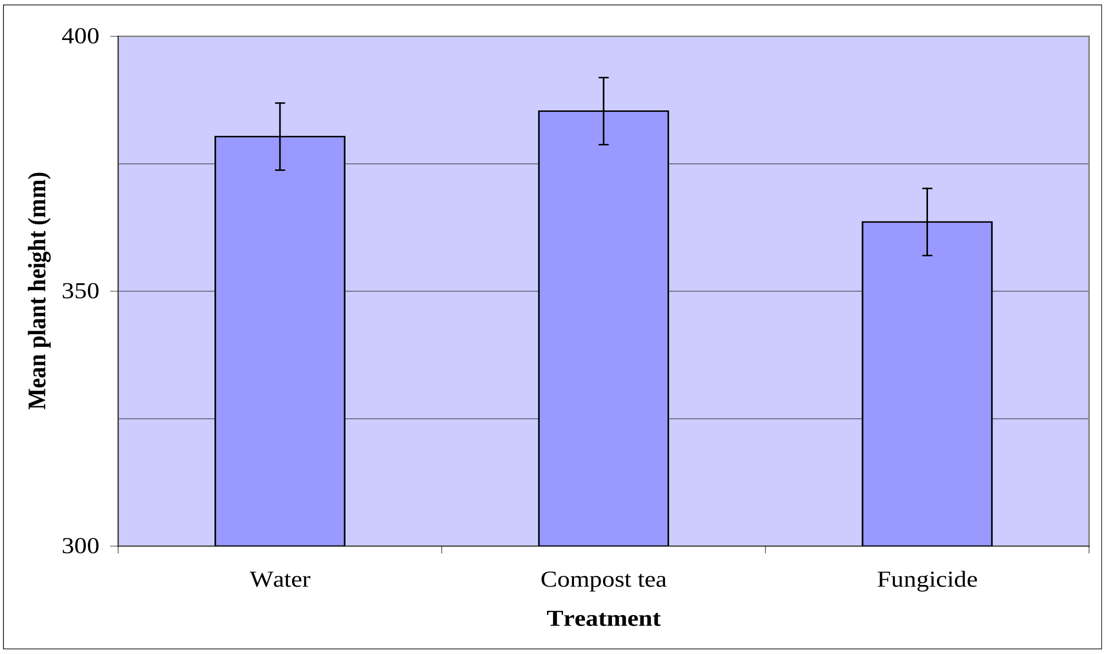

Figure 17. Effect of compost tea and fungicide on mean plant height (mm) of *Phygelius* 'Orange Fanfare' on 29th July 2005, 9 months after potting (Trial 6, Aline Fairweather). Error bars represent standard error of the mean (SEM).

Phygelius plants treated with compost tea had a significantly greater number of breaks (p=0.05) than those treated with plain water or fungicide (Table 12, Figure 18). There was no significant difference in the number of breaks of plants treated with plain water or fungicide (p=0.05).

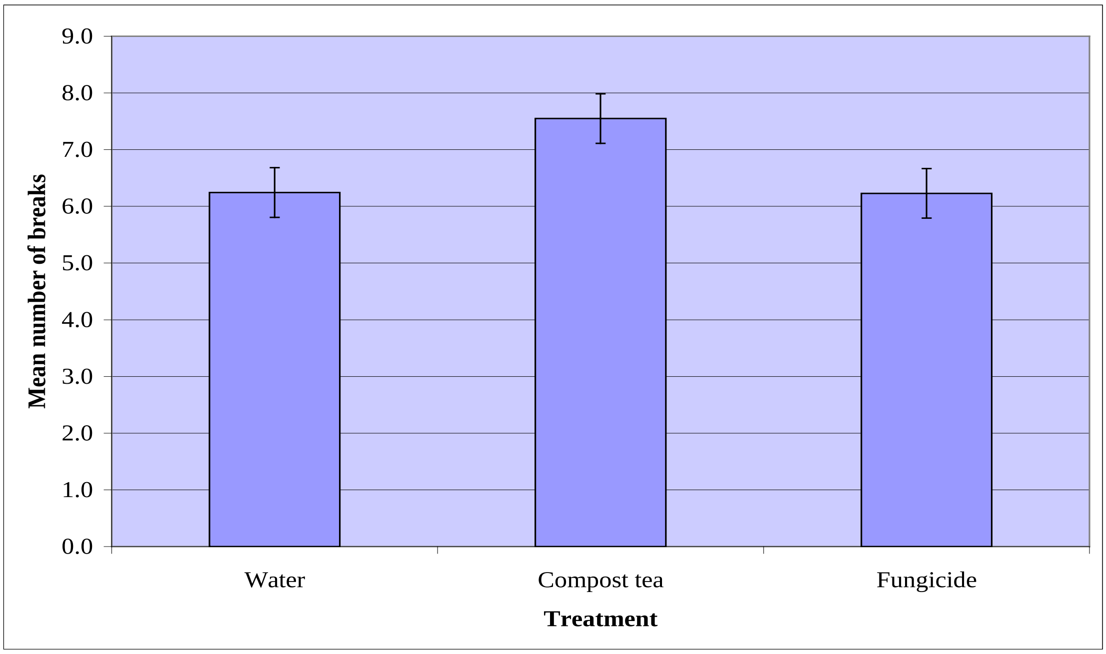

Figure 18. Effect of compost tea and fungicide on mean number of breaks of *Phygelius* 'Orange Fanfare' on 29th July 2005, 9 months after potting (Trial 6, Aline Fairweather). Error bars represent standard error of the mean (SEM).

Phygelius plants treated with compost tea had significantly higher root and quality scores than those treated with plain water or fungicides (p=0.05, Table 12, Figure 19). There was no significant difference (p=0.05) between the root scores of plants treated with plain water or compost tea. Similarly, there was no significant difference (p=0.05) in quality scores of plants treated with plain water and fungicides.

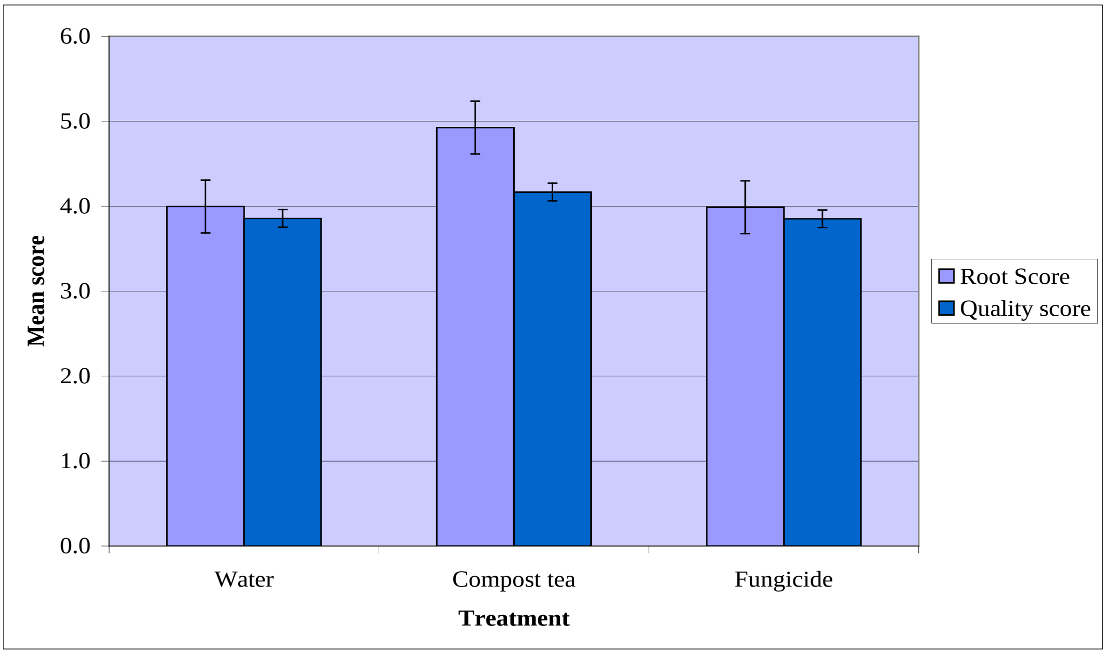

Figure 19. Effect of compost tea and fungicide on mean root and quality score of *Phygelius* 'Orange Fanfare' on 29th July 2005, 9 months after potting (Trial 6, Aline Fairweather). Error bars represent standard error of the mean (SEM).

There were no weeds or diseases recorded in the trial (Table 13). There was a low level of pest damage throughout the trial, but there was no significant difference in incidence of damage between treatments. Insect frass on the leaves and holes in the foliage were noted on several plants, which was thought to be the results of figwort weevil (*Cionus* sp.) feeding, although live adults were not found. Caterpillar damage was also seen across the entire trial and moderate numbers of active carnation tortrix moth (*Cacoecemorpha pronubana*) larvae were seen. Active lacewings (*Neuroptera* sp.) were found in the plants.

Table 13. Effect of compost tea and fungicide on the mean incidence of botrytis, leaf spot, dieback pests and weeds on *Phygelius* 'Orange Fanfare' on 29th July 2005, 9 months after potting (Trial 6, Aline Fairweather)

Treatment	Botrytis score	Leaf spot score	Dieback score	Pest score	Weed score
Water	5.0	5.0	5.0	4.0	5.0
Compost tea	5.0	5.0	5.0	4.1	5.0
Fungicides	5.0	5.0	5.0	4.1	5.0
Mean	5.0	5.0	5.0	4.1	5.0
LSD	**0**	**0**	**0**	**0.1**	**0**

Score: 0 = Dead or high incidence , 5 = No disease or pest (or damage from) observed

Discussion (Aline Fairweather trials)

***Lavandula* 'Violet lace'** **(Aline Fairweather)**

Although plants treated with compost tea were significantly taller than those treated with plain water at the final assessment, the relationship between the height of lavender plants in the three treatments was not the same on all four assessment dates. This inconsistent relationship between plant heights on different treatments may have been due to the fact that compost tea applications stopped or were less frequent in winter (when the height of plants treated with tea were same or lower than those recorded in other treatments). Application of fungicides and water continued throughout the winter. Compost tea did improve the long-term growth of the plants in comparison to the control and fungicide treatments, and it is this long-term improvement in growth which would be most important to the commercial grower.

Neither compost tea or pesticide application had an impact on the bushiness (number of breaks) in the plants grown. It is likely that plant trimming, which occurred twice during the trial had a greater impact on the plant habit than the treatments.

The root scores of lavender plants showed similar trends to those recorded for plant height. At the final assessment, plants treated with compost tea had significantly greater root scores than those treated with plain water. Plants treated with fungicide had root scores which were not significantly different to the control plants on three of the assessments. However, the fungicide-treated plants had significantly better root scores at the second assessment in March.

Again, this inconsistent relationship between root scores on different treatments may have been due to the fact that compost tea applications stopped or were less frequent in winter (when the root scores of plants treated with tea were same or lower than those recorded in other treatments). Application of fungicides and water continued throughout the winter. In the longer term, compost tea was shown to improve the root score of plants in comparison to the control treatment and pesticide application.

The low level of caterpillar damaged recorded throughout the lavender plants was common to all other crops grown in the same polytunnel and was not specific to the lavenders. The low level of weed incidence noted in the trial was likely the result of sand-bed irrigation used at the nursery.

***Phygelius* ‘Orange Fanfare’ (Aline Fairweather)**

The relationship between plant height and treatment differed between assessments. However, plants treated with compost tea were taller at the final assessment, which showed that compost tea improved the long-term growth of the plants.
Phygelius plants treated with compost tea had a significantly greater number of breaks than those treated with water or fungicide at all of the assessment dates. For this plant species, compost tea therefore had a positive effect on plant growth habit.

Phygelius plants treated with compost tea consistently had greater or the same root scores as plants treated with plain water (control), whilst plants treated with fungicide consistently had the same root scores as the control. Compost tea therefore had a positive effect on the root system development of this species, whilst fungicide application had no effect.

At all assessment dates, phygelius plants treated with compost tea had significantly greater quality scores than those treated with plain water, whilst plants treated with fungicide were found to have the same quality score as the control. Compost tea application therefore was associated with improved quality of the plants grown throughout the life of the trial, whilst pesticide application had no impact on the quality of crops grown, as noted with other species.

Again, it is thought that the sand-bed irrigation used on the nursery encouraged the very low level of weed incidence throughout the trial.

Results for West End Nurseries Trials

***Cordyline australis* ‘Torbay red’ (West End Nurseries)**

<u>First, second and third assessments (4, 8 and 10 months after potting)</u>
At the first two assessments, cordyline plants treated with compost tea were significantly shorter than those treated with plain water (control plants), but were then significantly taller than the control plants at the final two assessments

Cordyline plants treated with compost tea had consistently greater root scores than those treated with plain water at all assessment dates.

At the second assessment date, the quality scores of cordyline plants treated with compost tea or fungicides were significantly poorer than the controls (treated with plain water). At the following assessment the quality scores recorded on plants treated with compost tea were significantly greater than the controls, whilst those recorded on plants treated with fungicide were not.

There was very little evidence of pests, diseases or weeds at the first three assessment dates and there were no significant differences in incidence of disease, pests or weeds between the treatments.

Final Assessments (12 months after potting)

Cordyline plants treated with compost tea were significantly taller ($p=0.05$) than those treated with plain water or fungicides (Table 14, Figure 20). There was no significant difference between the height of plants treated with plain water or fungicides.

Table 14. Effect of compost tea and fungicides on the mean height, root score and quality score of *C. australis* 'Torbay red' plants on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries)

Treatment	**Plant height (mm)**	**Root score**	**Quality score**
Water	518	4.2	4.5
Compost tea	527	4.6	4.7
Fungicides	521	4.1	4.4
Mean	522	4.3	4.5
LSD	**16**	**0.3**	**0.2**

Root score: 0 = no visible roots when pot was removed, 5 = large numbers of roots visible
Quality score: 0 = Dead or poor plant, 5 = Very high quality plant

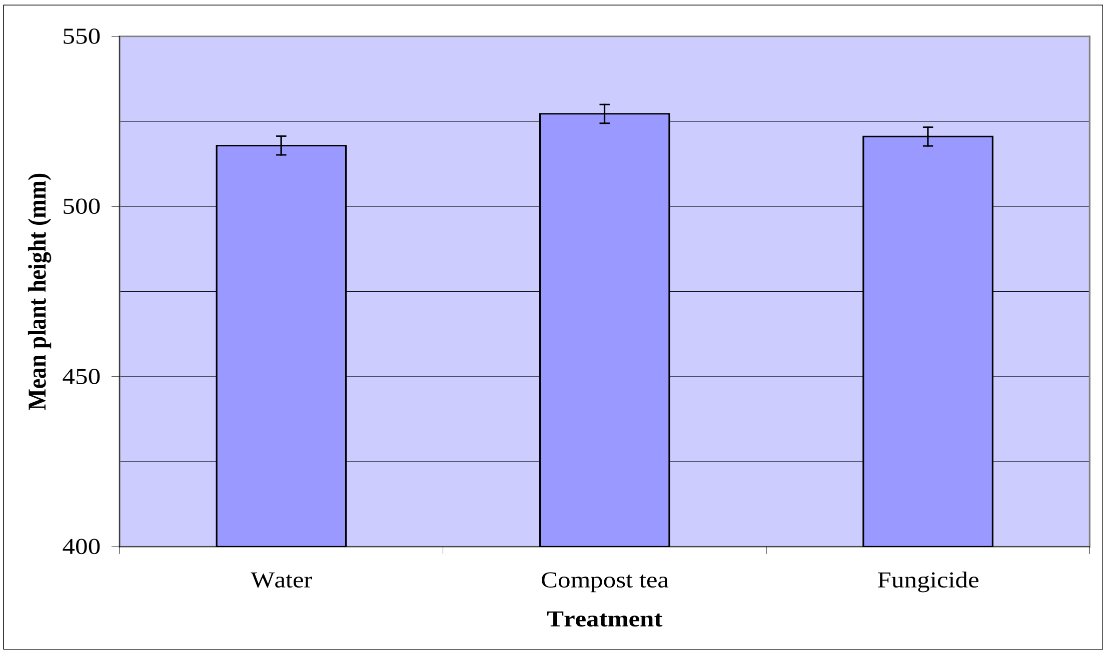

Figure 20. Effect of compost tea and fungicide on mean plant height (mm) of *C. australis* 'Torbay red' plants on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries). Error bars represent standard error of the mean (SEM).

Cordyline plants treated with compost tea had significantly greater root and quality scores (p=0.05) than those treated with plain water or fungicides (Table 14, Figure 21). There was no significant difference (p=0.05) between the root scores recorded on plants treated with plain water or fungicides. Similarly, there was no significant difference (p=0.05) between the quality scores of plants treated with plain water or fungicides..

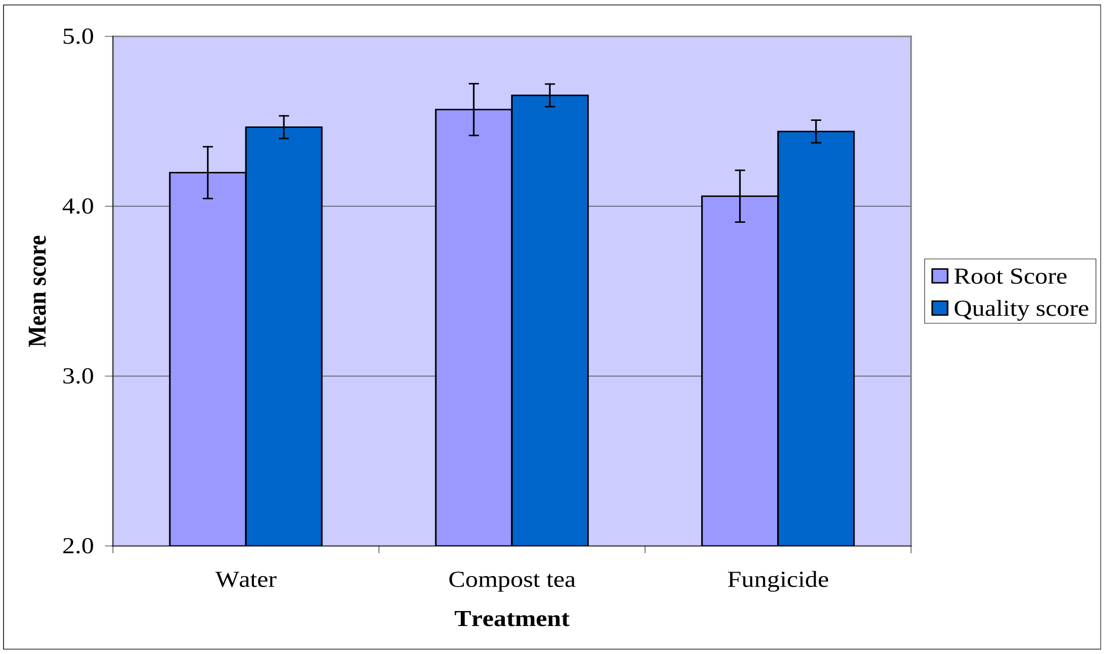

Figure 21. Effect of compost tea and fungicide on mean root and quality scores of *C. australis* plants on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries 5). Error bars represent standard error of the mean (SEM).

There were no diseases detected on the cordyline plants (Table 15). There was a moderate level of pest damage throughout the plants, but no significant difference in incidence of damage between treatments. The primary cause of the pest damage was slug and snail feeding, which was seen across the treatments. Small numbers of active slugs and snails were seen, although these were often seen on the sides of pots due to the time of day of the assessment. There was a moderate level of weed incidence, but no significant differences in incidence between treatments. The main weed found was moss, although pearlwort (*Sagina subulata*) and hairy bittercress (*Cardamine pratensis*) were also recorded. Some of the crowns of the plants were badly bent, rendering them unsaleable. The likely cause of this problem was physical damage when the trays were removed to apply treatments.

Table 15. Effect of compost tea and fungicides on the mean incidence of botrytis, leaf spot, dieback pests and weeds on *C. australis* 'Torbay red' plants on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries)

Treatment	**Botrytis score**	**Leaf spot score**	**Dieback score**	**Pest score**	**Weed score**
Water	5.0	5.0	5.0	4.1	4.2
Compost tea	5.0	5.0	5.0	4.0	4.3
Fungicides	5.0	5.0	5.0	4.0	4.3
Mean	5.0	5.0	5.0	4.1	4.3
LSD	**0**	**0**	**0**	**0.1**	**0.1**

Score: 0 = Dead or high incidence , 5 = No disease or pest (or damage from) observed

***Lavandula* 'Willowbridge calico' (West End Nurseries)**

First, second and third assessments (4, 8 and 10 months after potting)

During the first three assessments, lavender plants treated with compost tea or fungicide had the same as, or poorer root scores than those treated with plain water (controls).

Lavender plants treated with compost tea had higher quality scores than those treated with plain water (controls) on all of the first three assessment dates. Plants treated with fungicide consistently had the same or poorer quality scores than the controls. Plant heights were not measured during the first three assessments.

At the second assessment in March, lavender plants treated with compost tea or fungicides had a higher incidence of botrytis than plants treated with plain water. At the following assessment however, there was no significant difference in disease incidence between treatments.

Final Assessments (12 months after potting)

Lavender plants treated with compost tea or fungicides were significantly taller (p=0.05) than those treated with plain water (Table 16, Figure 22). There was no significant difference between the height of plants treated with compost tea and fungicide. The mean number of breaks per plant were not recorded in this trial.

Table 16. Effect of compost tea and fungicide on the mean height, root score and quality score of *Lavandula* 'Willowbridge calico' plants on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries)

Treatment	Plant height (mm)	Root score	Quality score
Water	517.9	4.2	4.5
Compost tea	527.2	4.6	4.7
Fungicides	520.6	4.1	4.4
Mean	521.9	4.3	4.5
LSD	**11.2**	**0.4**	**0.3**

Root score: 0 = no visible roots when pot was removed, 5 = large numbers of roots visible
Quality score: 0 = Dead or poor plant, 5 = Very high quality plant

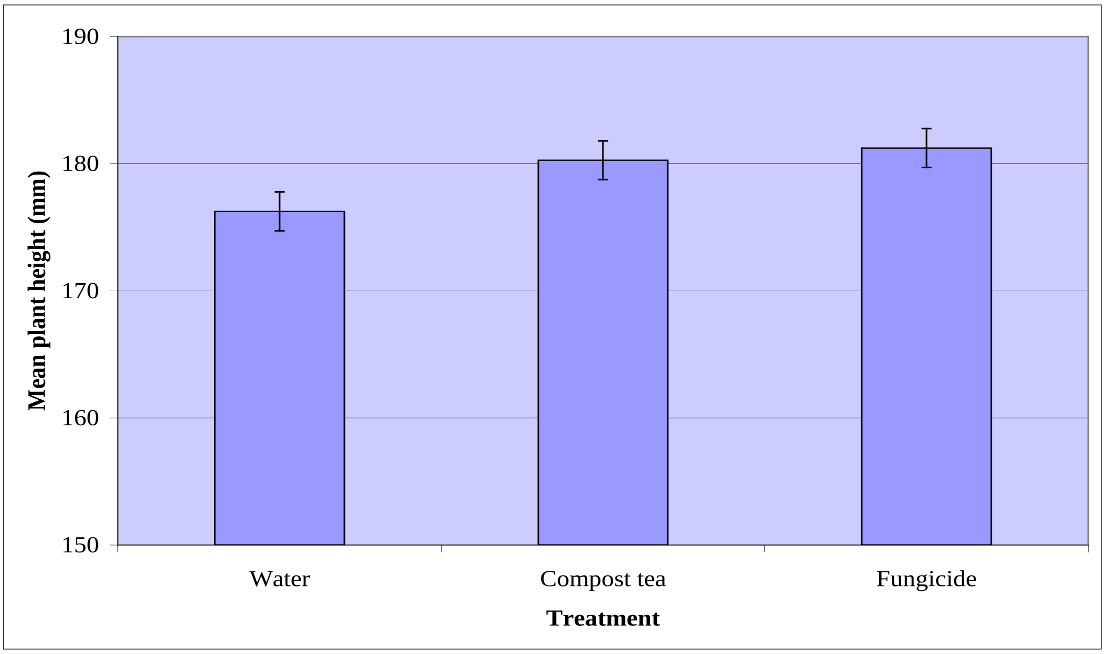

Figure 22. Effect of compost tea and fungicide on mean height of *Lavandula* 'Willowbridge calico' plants on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries). Error bars represent standard error of the mean (SEM).

Lavender plants treated with compost tea had significantly greater root and quality scores (p=0.05) than those treated with plain water or fungicides (Table 16, Figure 23). There was no significant difference (p=0.05) in the root scores recorded on plants treated with plain water or fungicides. Similarly, there was no significant difference (p=0.05) in the root scores recorded on plants treated with plain water or fungicides.

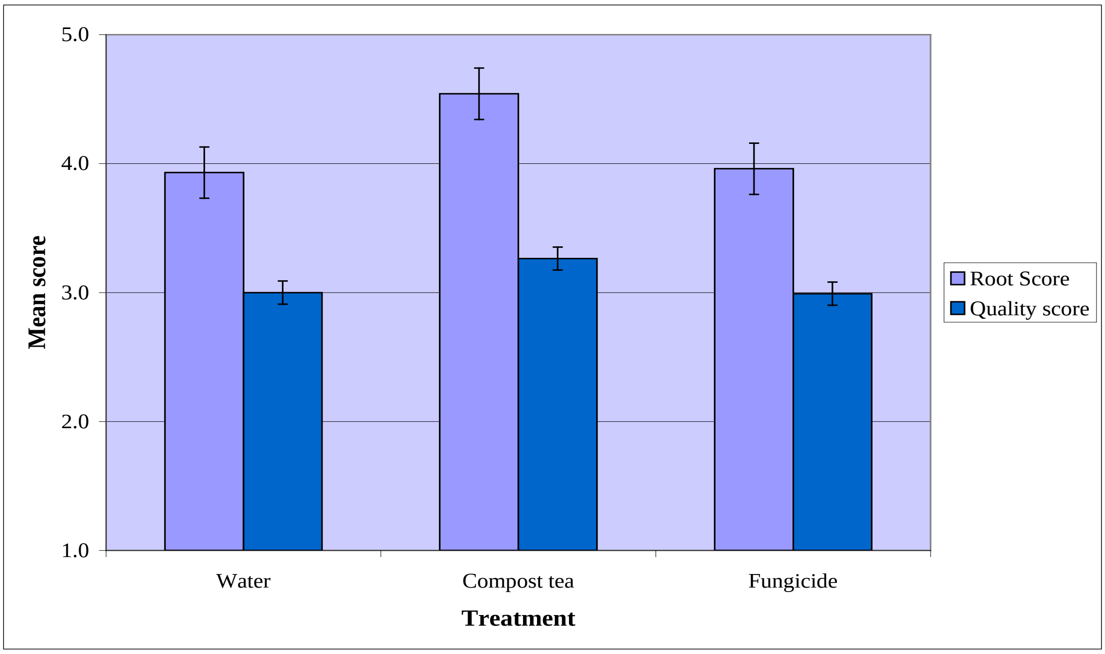

Figure 23. Effect of compost tea and fungicide on mean root and quality scores of *Lavandula* 'Willowbridge calico' on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries). Error bars represent standard error of the mean (SEM).

There were no diseases detected on the Lavender plants (Table 17). A very low level of slug damage was noted on the plants, but there was no significant difference in incidence of damage between treatments. There was a moderate level of weed incidence, and plants treated with fungicide were found to have significantly more weeds (p=0.05) than those treated with compost tea or plain water (Table 17, Figure 24). The main weed found was moss, although pearlwort and annual meadow grass (*Poa annua*) were also seen. Mites (*Hypoaspis* sp). were observed in a number of the root systems examined.

Table 17. Effect of compost tea and fungicide on the mean incidence of botrytis, leaf spot, dieback pests and weeds on *Lavandula* 'Willowbridge calico' on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries)

Treatment	Botrytis score	Leaf spot score	Dieback score	Pest score	Weed score
Water	5.0	5.0	5.0	5.0	4.9
Compost tea	5.0	5.0	5.0	4.9	4.8
Fungicides	5.0	5.0	5.0	5.0	4.7
Mean	5.0	5.0	5.0	5.0	4.8
LSD	**0**	**0**	**0**	**0**	**0.1**

Score: 0 = Dead or high incidence , 5 = No disease or pest (or damage from) observed

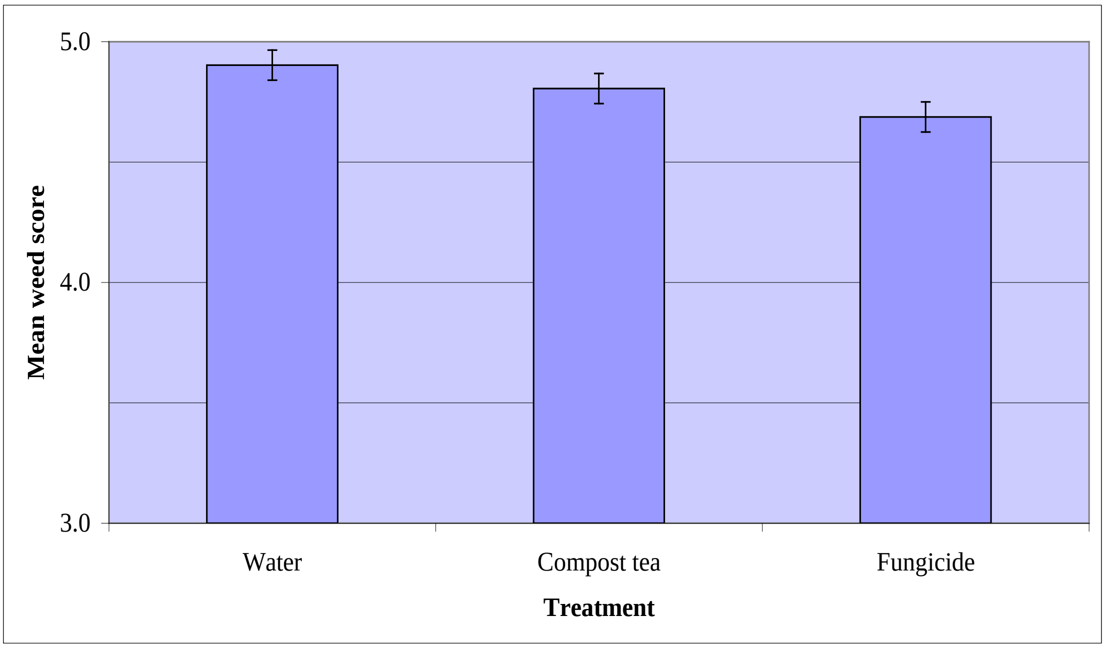

Figure 24. Effect of compost tea and fungicide on mean weed score in *Lavandula* 'Willowbridge calico' pots on 2nd August 2005, 12 months after potting (Trial 6, West End Nurseries). Error bars represent standard error of the mean (SEM).

Discussion (West End Nurseries Trials)

***C. australis* 'Torbay red' (West End Nurseries)**

Results in the early stages of the trial suggested that the growth of cordyline plants treated with compost tea declined during the winter months when tea applications stopped or were less frequent. Growth of tea-treated plants then improved in comparison with plants on other treatments during the spring and summer months and taller plants resulted. Plants treated with fungicides were not significantly taller than the control plants at three of the plant assessments including the final assessment, indicating that fungicide application had no or little effect on plant growth.

Plants treated with compost tea had significantly greater root scores than those treated with plain water or fungicide. These results indicate that whilst pesticide application had no impact on root growth, compost tea consistently boosted the root growth for this species.

The quality of plants treated with compost tea or fungicides deteriorated during the winter months in both treatments, but application of compost tea was associated with improved plant growth in the spring in comparison to the conventional fungicide application.

At the final assessment there was a moderate level of slug and snail damage throughout the trial, although this was observed on other crops in the same polytunnel, which would indicate that the treatments were not a factor in the incidence of the pests. The occurrence of moss in the trial was thought to be due to the overhead irrigation system, which can encourage moss more than sandbeds (as used in the trial at Aline Fairweather, where no moss was seen).

***Lavandula* 'Willowbridge calico' (West End Nurseries)**

The relationship between plant height and treatment differed between assessments. However, plants treated with compost tea were taller at the final assessment, which showed that compost tea improved the long-term growth of the plants.

During the first three assessments, plants treated with compost tea or fungicide had the same as, or poorer root scores than those treated with plain water (controls). At the final assessment however, plants treated with compost tea had greater root scores than the controls, whilst plants treated with fungicide were no different to the controls. Compost tea was therefore associated with improved root growth over the longer term, i.e. the normal length of time that this species would spend in a pot of this size.

Whilst pesticide application had no (or little) impact on plant quality in comparison with the control plants, compost tea improved plant quality in all four assessments over the 12 month trial period.

During the winter months when compost tea and fungicide applications stopped or were less frequent, disease appeared to increase. However, the plants in treatments 2 and 3 (compost tea and fungicide respectively) recovered in subsequent months, perhaps as a result of applications resuming or increasing in frequency. There is no obvious explanation as to why the pots of plants treated with fungicide contained more weeds than the other treatments at the final assessment.

Results for Notcutts Trial

***Rosa* 'Oxfordshire'**

The trial was assessed on four dates in 2005 (28th January, 26th April, 26th July and 28th September). There were no significant differences in plant height, the number of shoots or plant losses between treatments on any of the four assessment dates. The roses grew normally, although the pots became heavily infested with liverwort towards the end of the trial period. This problem was seen across the whole trial and there was no significant difference in the level of liverwort infestation between treatments.

No pests or diseases were observed on 28th January 2005. Downy mildew (*Peronospora sparsa*) was observed in the trial on 26th April. There were no significant differences in disease incidence between treatments. Plant losses were recorded at the second, third and final assessments (5.0, 4.8 and 3.3 dead plants per treatment on the final assessment for plants treated with plain water, compost tea and fungicides respectively). These differences were not significant. No pests or diseases were observed in the trial on the final assessment.

Additional assessments were carried out on both pests and biological control agents on 11 May, 28 July and 31 August 2005. On 11 May, the main pests recorded were aphids, although these were in very low numbers, with a mean of less than one aphid per plant in all three treatments (Figure 25). Three species of aphid were recorded: the potato aphid (*Macrosiphum euphorbiae*), the glasshouse and potato aphid (*Aulacorthum solani*) and the peach-potato aphid (*Myzus persicae*). Low numbers of parasitised aphids were also found: *M. persicae* were parasitised by *Aphidius colemani* which was released every 2 weeks by the grower, and there was also a low incidence of parasitism by *Praon* sp. which were naturally-occurring. The number of parasitised aphids were recorded on the plots treated with fungicides (See Appendix II, Table 10) .

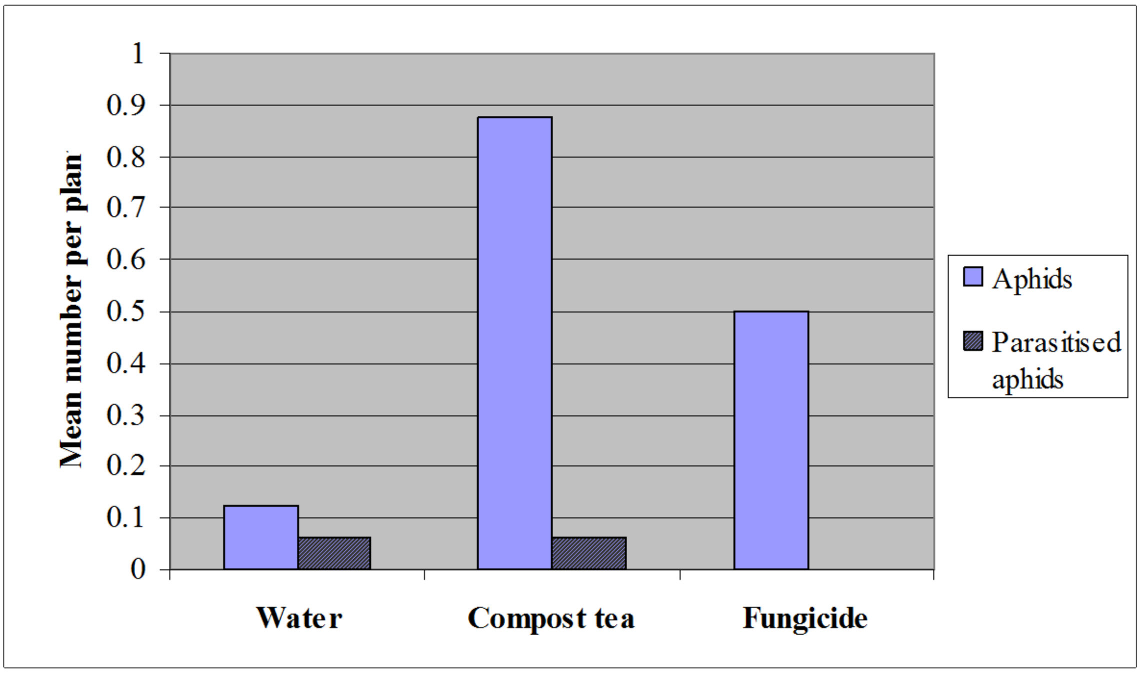

Figure 25. Mean numbers of healthy and parasitised aphids per plant on *Rosa*, 11 May 2005.

The data was not subjected to statistical analysis because the plants were extremely variable in size due to excessive liverwort growth smothering some pots and to the fact that the plants had not been trimmed as they would have been under normal commercial practice. This variation in plant size would have affected the numbers of aphids present. In addition to aphids, very low numbers of slugs (*Deroceras panormitanum*), snails (*Oxyloma pfeifferi*) and glasshouse whitefly adults (*Trialeurodes vaporariorum*) were recorded.

On 28 July, the only pests present were two-spotted spider mite (*Tetranychus urticae*), and the infestation and damage symptoms were severe on all plants and all leaves in every plot. The grower had released the predatory mites, *Phytoseiulus persimilis* at the first sign of the pest, but there had been a rapid increase in spider mite numbers in the hot, dry conditions during mid-late July, when the grower was on holiday. A tank mix of two acaricides, Dynamec (abamectin) and Apollo 50 SC (clofentezine) was applied by the grower on 27 July to control the spider mites. On 28 July, four leaves from each of four plants per plot were assessed for numbers of live spider mites and *P. persimilis*. A mean of 6-7 live spider mites and 1-2 live *P. persimilis* per leaf were recorded on all three treatments (Figure 26). In addition, low numbers of naturally-occuring predatory midge larvae and cocoons, *Feltiella acarisuga*, were recorded. The data were not subjected to statistical analysis because the numbers of spider mites and predators were similar in all three treatments, and numbers would have been affected by the acaricides applied the day before the assessment.

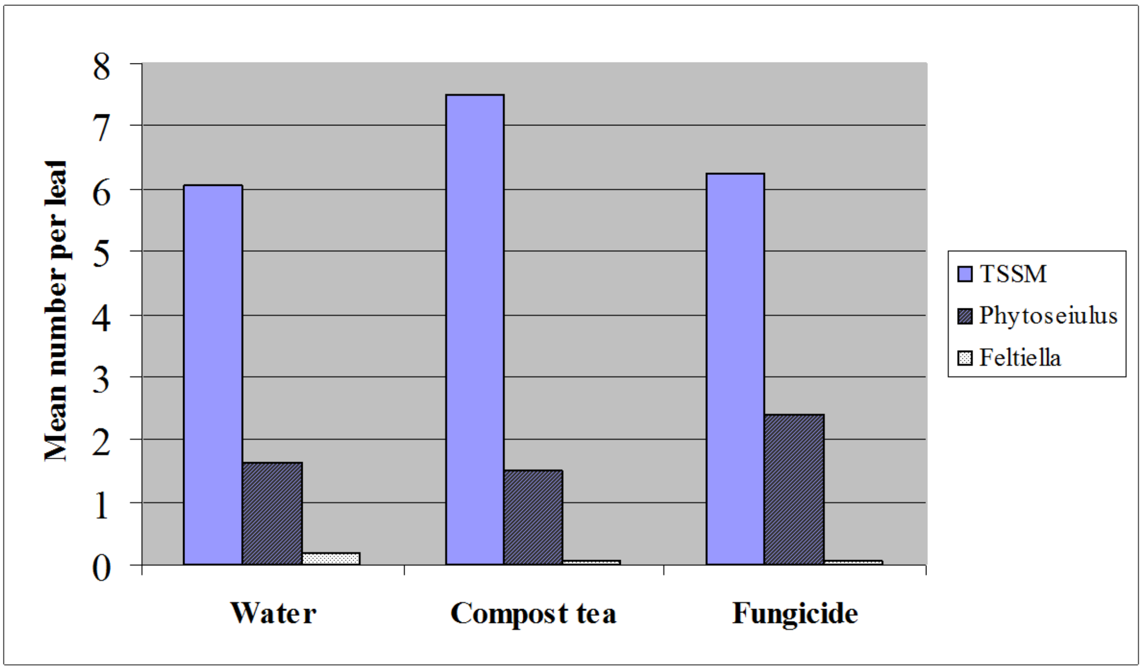

Figure 26. Mean numbers of 2-spotted spider mite, *Phytoseiulus persimilis* and *Feltiella acarisuga* per plant on *Rosa*, 28 July 2005.

On 31 August, no further spider mites were recorded and the only pest observed was western flower thrips (WFT), *Frankliniella occidentalis*, in flowers and flower buds. A full assessment of thrips numbers in each plot was not possible because the thrips were only present on the few plants with flower buds or open flowers present, and these plants were not present in some plots and were only present in low numbers in other plots.

Discussion (Notcutts trial)

There were no significant differences in plant height, the number of shoots, plant losses or pest and disease incidence/severity between treatments on any of the four assessment dates. The growers producing roses at Notcutts have observed improved rose health and quality as a result of cutting the quantity of fungicides applied and implementing a compost tea application programme during the past 2 years. The results obtained in this trial are therefore not what were expected. There were some problems with the trial, which may have affected the results. The roses grew normally during the first 6 months, but the pots became heavily infested with liverwort towards the end of the trial period and plant quality declined. Had the liverwort been treated before it was allowed to develop, plant health may have been maintained and differences between treatments observed. The trial was limited in size in order to reduce the cost of the plants to the grower. In retrospect, it may have been better to run the trial over a larger area, since any beneficial effects (particularly disease suppressive) effects may have been reduced by the proximity of commercial crops which were being treated with fungicides. In addition, the trial was not surrounded by other roses (apart from guard rows) during the last 3 months, as the adjoining commercial crop was sold.

Finally, the compost tea and water treatments may have received more water than the fungicide treatment. This may have affected results, especially those concerning plant deaths, which may have been due in part to water-logging. Consideration should be given to reducing the volume of water applied with compost teas, especially in the winter months.

On 11 May, it was difficult to assess any effect of treatment on numbers of aphids on 11 May due to excessive liverwort growth and lack of plant trimming leading to large variation in the size and vigour of the plants. However, low numbers of aphids were observed on plants in all three treatments and parasitised aphids were observed in both water and compost tea-treated plots, indicating that treatment with compost tea did not affect aphid parasitoids. Parasitism levels are likely to have been higher if the grower had been releasing the appropriate biological control agents for the aphid species present. Following the assessment on 11 May, the grower was advised to release an additional parasitoid, *Aphidius ervi* and the predatory midge, *Aphidoletes aphidimyza*, as his releases of *Aphidius colemani* would only have been controlling one of the aphid species present, *M. persicae.* Additional evidence for the hypothesis that compost teas do not affect aphid parasitism was given by experience at the Notcutts propagation nursery, where regular compost teas were applied during 2005 and no adverse effects on aphid parasitism was observed by the grower.

The high numbers of spider mites and presence of *Phytoseiulus* on all plants and plots on 28 July indicated that there was no effect of treatment on either the pest or the predatory mites. The severity of the infestation was considered to have been due to the very hot, dry conditions in the two weeks preceeding the assessment, which would have favoured the spider mites and disadvantaged the predators. Roses are very susceptible to spider mites and biological control has to be monitored carefully, using a compatible acaricide if and when necessary if the predators start to lose control. It was unfortunate that the grower was on holiday during this critical period, leading to a severe outbreak of the pest. The isolated position of the trial area is likely to have exacerbated the hot, dry conditions for the experimental plants during this period, as all surrounding plants had been sold.

On 31 August, it was not possible to assess the effect of treatments on the WFT infestation, as thrips were found only on the few plants with flower buds or open flowers and these were not present in every plot. The occurrence of WFT only in flower buds or flowers is typical of WFT on roses and certain other flowering plants, where the thrips prefer flowers to leaves. The grower had been releasing the predatory mites, *Amblyseius cucumeris* and was advised to increase the release rate following the assessment on 31 August, as petal damage was beginning to occur.

OVERALL DISCUSSION

Lavender, choisya, cordyline and phygelius plants treated with compost teas in the nursery trials (Trial 6) were frequently better (in terms of plant height, plant quality and root score) than those treated with plain water and in some cases fungicides by the final assessment. There were frequently no differences between treatments at earlier assessments. Lavender, choisya, cordyline and phygelius plants treated with compost teas in these trials rarely had less damage due to pests, diseases or weeds than those treated with plain water or fungicides. The roses which were treated with compost teas in Trial 6 at Notcutts were no better (in terms of plant height, plant quality, root score or pest/disease incidence) than those treated with plain water or fungicides at any assessment. Similarly, there were rarely any differences in observed parameters (plant height, number of flower spikes, shoot dry weight, amount of disease/pest damage), on lavenders or choisyas treated with compost tea, fungicides or plain water.

Despite the fact that the use of compost teas was associated with improved plant growth and quality in several ornamental species in the nursery trials at the final assessment, this performance was not consistent across every assessment. Nor was it consistent across every species in the nursery trials. Compost teas rarely had any positive effects in Trials 1 – 4 either. Compost teas rarely had deleterious effects either.

There are several reports in the scientific literature of trials in which compost teas have had no effects or inconsistent effects on plant growth and health in comparison to plain water controls or fungicide treatments (Scheuerell & Mahaffee, 2004; Litterick *et al*., 2004). Although there is a general understanding of the mechanisms whereby compost teas work, there is little understanding of the details. Compost teas are thought to have a small fertilising effect on plants: they may improve plant nutrition and possibly plant resistance to pest and/or disease attack (Scheuerell & Mahaffee, 2002). They are thought to improve the balance of beneficial organisms on and around the root, thereby enhancing root function, resistance to root/stem-base diseases and the plant's ability to take up nutrients. Finally, they are thought to improve the balance of beneficial organisms on the leaf/stem surfaces, in this way enhancing resistance to foliar diseases.

The study of microbial dynamics on leaf surfaces and in soils and growing media is extremely complex and is still in its infancy. Even to study the survival and population dynamics of single, introduced fungal or bacterial biological control agents in crop production systems is time-consuming, difficult and expensive. The study of complex mixed populations of fungi, bacteria, actinomycetes and protozoans present in compost tea has so far not been attempted to any extent with a view to being able to produce reliably effective compost teas (apart from by Dr Elaine Ingham of Soil Foodweb Inc. who has not published her results due to commercial confidentiality). Dr Ingham's instructions on how to produce "good teas" were followed when designing the trials in this project and when making the compost teas (http://www.soilfoodweb.com/03_about_us/approach.html). However, inconsistent results were still obtained when using the teas.

In future work, it is likely that modern, high-throughput biotechnological methods for evaluating the functional or genetic diversity of microbial populations in compost teas and growing media will provide the quickest, cheapest way to assess the effect of different preparation/application factors on the microbial composition of the tea and to elucidate whether the performance of individual teas is related to their microbial composition.

Part of the reason for poor performance of the compost teas (in comparison with recent American work) may have been inappropriate trial design. Small-scale, replicated plot trials may not be the best way of evaluating the performance of compost teas. There is evidence from organic farming research, that small-scale, reductionist trials are an inappropriate way to evaluate the performance of partial solutions to pest and disease problems (Atkinson *et al*., 2002; Litterick *et al*., 2002). Such partial solutions (e.g. application of organically approved treatments such as garlic and equisetum extracts) only work as part of the full organic system. They rarely work well when tested on conventional farms when compared with conventional pesticide treatments, because the wide range of beneficial organisms which are normally present on organic farms (and which contribute towards pest and disease control) are not present on conventional farms.

It may be the case that compost teas also tend to have greatest beneficial effects when used on a large scale and when broad-spectrum pesticide use is minimal. This may explain why the compost teas used in the nursery trials (Trial 6) had generally beneficial effects on plant growth/health, yet those used in Trials 1 to 4 did not (they took place on a trials facility which uses pesticides fairly regularly). Similarly, many of the commercial nurseries now using compost teas with apparent success have also reduced their fungicide programme or have stopped using fungicides altogether.

In future, nursery-based trials with multiple sampling points within large (perhaps full tunnel) plots would be most likely to yield useful information. Plants from these multiple sampling points would be assessed for quality, incidence/severity of pest attack/diseases. Effects on biological control agents may be better assessed in large plots.

CONCLUSIONS FROM TRIALS 1 TO 6

Trial 1 - Effect of teas made using four brewers on ornamental crops

- None of the compost teas used had any effect on the growth of lavenders or choisyas (plant height or shoot dry weight), disease (*Botrytis cinerea*) or pest damage (two-spotted spider mite) when compared with plants treated with fungicides or plain water.
- The type of brewer used therefore had no effect on the quality of lavender or choisya plants or their susceptibility to pests or diseases. In summary, the type of brewer used had no effect on the quality of lavender or choisya plants or their susceptibility to pests or diseases.
- Shipping costs make both of the American brewers expensive. There was a problem with the pump on the Earth Tea brewer within a month of purchase, and parts proved difficult and costly to obtain. The Earth Tea Brewer also tended to produce a tea which was 2 to 5^0C warmer than ambient, since the tea is used to cool the pump during production. This is undesirable, particularly during the warm summer months, when tea temperatures can easily become higher than the optima for many of the organisms within the brew. The American brewers were both more complex than the two UK models and were slightly more difficult to clean and maintain. Considering the cost, the difficulty of obtaining spare parts and the lack of evidence that they make better compost teas, there is no reason to suggest that UK growers should buy the American brewers.
- The Reading Compost Brewer performed well, was easy to clean and maintain and would be an excellent choice for growers wishing to try using compost teas on a small scale. Reading Compost Brewers have brought out a new, improved model since the one used in trials was obtained. They have also introduced a larger model.
- The Xtractor proved robust, reliable and is easily maintained. It seems very expensive for what it is, but it remains the only large compost tea brewer which is easily available for UK growers to buy at present.

Trial 2 - Effect of compost type on the efficacy of compost tea

- There were rarely any differences in the growth (plant height or shoot dry weight), disease severity (*Botrytis cinerea*) or pest damage (two-spotted spider mite) on lavenders or choisyas treated with compost tea, fungicides or plain water.
- The effect of compost type used to make tea on the quality of lavender or choisya plants and on their susceptibility to pests or diseases was complex. Where treatment differences were observed between teas made from different composts, the poorest quality plants were usually those treated with tea made from van Iersel compost.

Trial 3 - Effect of compost age (maturity) on the efficacy of compost tea

- There were no significant differences between the numbers of flower spikes, plant height, amount of botrytis or shoot dry weight recorded on lavender plants treated with compost tea made from composts of different ages (and CO_2 evolution rates).
- There were significantly more side shoots on lavender plants treated with compost tea made with young compost than on those in other treatments. Lavender plants treated with compost tea made with van Iersel compost, mature compost or fungicide had the lowest number of side shoots.
- Choisya plants treated with plain water, fungicide or compost tea made either van Iersel compost or old greenwaste compost had significantly lower levels of mildew than those treated with compost tea made with either young or mature compost.
- There were significant differences between the height of choisya plants in different treatments. Plants treated with plain water or fungicides were significantly shorter than those in other treatments.
- There were significant differences between the amount of damage caused by two-spotted spider mite on choisya plants in different treatments at harvest. Plants treated with compost tea made with van Iersel compost had significantly greater spider mite damage than those in other treatments. Plants treated with plain water, fungicides or compost tea made from old greenwaste compost had the least damage.
- In summary, the effect of the maturity of compost used to make tea on the quality of lavender or choisya plants and on their susceptibility to pests or diseases was complex. There were frequently no differences in observed parameters between treatments. Where treatment differences were observed between teas made from composts of different ages, the treatment in which the best quality plants were found differed depending on the quality parameter being measured.

Trial 4a - Effect of pre-brewing additives on compost tea performance

- There were no differences between performance of teas made with van Iersel composts with the proprietary pre-brewing kit and van Iersel composts made with similar, separately obtained pre-brewing additives.
- There were no differences between performance of teas made with CMC composts, herbs, sugar and nutrients and CMC composts made using sugar and nutrients alone.
- In summary, there was insufficient evidence to show that differences in pre-brewing additives have any effect on the performance of compost teas.

Trial 4b - Effect of post-brewing additives on compost tea performance

- There was insufficient evidence to show that post-brewing additives had any effect on the performance of compost teas on lavender.
- Choisya plants treated with compost tea containing brewing additives were significantly heavier than those made with van Iersel compost alone. However, choisyas treated with compost tea made with van Iersel compost without post-brewing additives were of significantly higher quality than those treated with van Iersel compost with post-brewing additives. In other words, although choisya plants treated with compost tea without brewing additives tended to be lighter, they also tended to be shorter and more compact (and therefore of higher quality).

Objective 5 - Assessment of the characteristics of compost teas used in trials

- Plate counts showed that the numbers of total culturable bacteria recorded from brews in Trials 1, 2, 3, 4a, 4b and 6 were within the range reported for disease suppressive compost teas (i.e. they were between 10^7 to 10^{10} CFU per ml).

- There was no evidence of *Salmonella* species and there were very low numbers of *E. coli* in the compost teas used in this work.

- The compost teas had pH values of 7.1 to 7.4, eC values of between 459 and 1650 μS/cm and contained a good supply of macronutrients (P, S, K, Ca and Mg) and micronutrients (Fe, Cu B and Zn). The supply of each of these elements either singly or in combination (synergistic effects) could play a role in the beneficial effects of compost teas on plant growth and development including disease resistance

- When tested, the composts used in this work were found to be of high quality. They would all have passed the criteria required to conform with the British Standards Institution Publicly Available Specification 100:2005 (PAS 100:2005) for composts. The pH values, salt concentrations, physical parameters and C:N ratios obtained were acceptable for composted products. Concentrations of plant available nutrients were appropriate for greenwaste composts and all of the composts were considered sufficiently stable according to (PAS 100:2005).

Trial 6 - Hewton Nurseries - Choisya *'Aztec Pearl'*

- Plants treated with compost tea were significantly shorter than those in other treatments at the final assessment, but not any bushier (i.e. they did not have more breaks) than those treated with plain water (control) or the standard fungicide programme at the final assessment.

- Whilst plants treated with compost tea or fungicide had significantly greater quality scores than control plants at the first assessment in December, the quality of plants treated with compost tea or fungicide deteriorated during the trial period. At the final assessment, plants treated with compost tea had significantly poorer root and quality scores than control plants. The deterioration in quality scores may have been due to the presence of excess water in the pots.

- There were no diseases present in the trial. There was a moderate level of pest damage throughout the trial, but no significant differences in the amount of pest damage between treatments. Plants treated with compost tea had significantly more weeds than those treated with plain water (control) or fungicide.

Trial 6 - Hewton Nurseries - *Cordyline australis*

- Plants treated with compost tea or fungicide were significantly taller than those treated with plain water.

- Plants treated with compost tea had significantly greater root scores than those treated with plain water or fungicide.

- At the first two assessments, *C. australis* plants treated with compost tea had significantly poorer quality scores than those in the control treatment. However, at the third and fourth assessments plants treated with compost tea had significantly greater root scores than the control and fungicide treated plants, and significantly greater quality scores than the control. The compost tea was therefore associated with an improvement in plant quality over the life of the trial.

- There were no significant differences in disease or weed incidence between treatments. There was a low level of pest damage throughout the trial. Plants treated with compost tea or fungicide had significantly fewer incidences of pest damage than the control treatment. Low levels of moss and liverwort were found on the plants, but there was no significant difference in incidence of these weeds between treatments.

Trial 6 - Aline Fairweather - *Lavandula* 'Violet lace'

- Plants treated with compost tea were significantly taller than plants treated with plain water or fungicide.

- Plants treated with compost tea had significantly greater root and quality scores than those treated with plain water or fungicide.

- There was no disease and no weeds in the trial. There was a low level of caterpillar damage on the plants, but no significant difference in incidence of damage between treatments.

Trial 6 - Aline Fairweather - *Phygelius* 'Orange Fanfare'

- Plants treated with compost tea or plain water were significantly taller than those treated with fungicide.

- Plants treated with compost tea had a significantly greater number of breaks and significantly higher root and quality scores than those treated with plain water or fungicide.

- There were no diseases or weeds recorded during the trial period. There was a low level of pest damage throughout the trial, but there was no significant difference in incidence of damage between treatments.

Trial 6 - West End Nurseries - *Cordyline australis* 'Torbay red'

- Plants treated with compost tea were significantly taller than and had significantly better root scores than those treated with plain water or fungicides at the final assessment.

- At the second assessment date, the quality scores of *C. australis* 'Torbay red' plants treated with compost tea or fungicides were significantly poorer than the controls (treated with plain water). At the following two assessments the quality scores recorded on plants treated with compost tea were significantly greater than the controls, whilst those recorded on plants treated with fungicide were not. The quality of plants treated with compost tea or fungicides deteriorated during the winter months in both treatments, but application of compost tea was associated with improved plant growth in the spring in comparison to the conventional pesticide application.

- There were no diseases detected on the plants. There was a moderate level of pest damage throughout the plants, but no significant difference in incidence of damage between treatments. There was a moderate level of weed incidence, but no significant differences in incidence between treatments.

Trial 6 - West End Nurseries - *Lavandula* 'Willowbridge calico'

- Plants treated with compost tea or fungicides were significantly taller than those treated with plain water.

- Plants treated with compost tea had significantly greater root and quality scores than those treated with plain water or fungicides.

- There were no diseases detected on the plants. There was a very low level of slug damage throughout the trial, but no significant difference in incidence of damage between treatments. There was a moderate level of weed incidence, and plants treated with fungicide were found to have significantly more weeds than those treated with compost tea or plain water.

Trial 6 – Notcutts – *Rosa* 'Oxfordshire'

- Compost teas had no effect on the height of *Rosa* 'Oxfordshire' plants, the number of shoots, disease incidence or severity, or the number of dead plants per plot in comparison with untreated and fungicide treated plants.

- It was not possible to fully assess the effect of compost teas on the severity of aphid infestation on roses, due to the low numbers of aphids recorded on the trial and to the wide variation in plant size and vigour due to excessive liverwort growth and to the lack of plant trimming during the trial period.

- Compost teas did not seem to adversely affect aphid parasitism on roses, by either released or naturally occurring parasitoids.

- Compost teas did not seem to affect the severity of spider mite infestation on roses, or have an adverse effect on *Phytoseiulus*.

- It was not possible to assess the effect of compost teas on the severity of WFT on roses, due to the low numbers of thrips recorded on the trial and to the patchy distribution of the pest on the few plants present with flower buds or open flowers.

OVERALL CONCLUSIONS FROM PROJECT

- Lavender and choisya plants treated with compost teas in Trials 1 to 4b were rarely better (in terms of plant height, quality or pest/disease incidence) than those treated with plain water or fungicides.

- Lavender, choisya, cordyline and phygelius plants treated with compost teas in the nursery trials (Trial 6) were frequently better (in terms of plant height, plant quality and root score) than those treated with plain water and in some cases fungicides.

- Lavender, choisya, cordyline and phygelius plants treated with compost teas in the nursery trials (Trial 6) rarely had less damage due to pests, diseases or weeds than those treated with plain water or fungicides.

- Roses treated with compost teas in Trial 6 were no better (in terms of plant height, plant quality, root score or pest/disease incidence) than those treated with plain water or fungicides.

- Despite the fact that the use of compost teas was associated with improved plant growth and quality in several ornamental species in the nursery trials (Trial 6), the performance of compost teas across the entire project was extremely inconsistent. Compost teas often had no effect, although they rarely had deleterious effects.

FUTURE WORK

- Considerable further work is required in order to develop a fuller understanding of how compost teas work, in order to develop reliable protocols for their use.

- Small-scale, replicated plot trials may not be the best way of evaluating the performance of compost teas on nurseries (see overall discussion from Trial 6). Results from trials carried out in this project suggest that nursery-based trials, with multiple sampling points within large (perhaps full tunnel) plots would be most likely to yield useful information. Plants from these multiple sampling points would be assessed for quality, incidence/severity of pest attack/diseases. Effects on biological control agents would also be better assessed in large plots.)

- Our understanding of the reasons why compost teas sometimes improve plant quality and health (and why they sometimes do not) are still poor. It is known that the beneficial effects of compost teas are largely due to microorganisms, but we do not yet know how to optimise the effects that these microorganisms have.

- Considerable investment is required, using modern microbial profiling techniques (e.g. to measure genetic or functional diversity) to determine the reasons why some compost teas work and some don't and to elucidate the best ways to optimise the efficacy of compost teas.

- There is demand from interested growers for a practical workshop on compost teas. Speakers would usefully include growers who have had success with compost teas and who understand the practical implications of implementing a compost tea programme, researchers with experience in using compost teas in experimental situations.

TECHNOLOGY TRANSFER

There has been a strong interest in compost teas in the UK during 2004 and 2005, not only in ornamental horticulture, but also in the waste management and compost production industries and in organic agriculture/horticulture. Audrey Litterick has been asked to speak at several seminars and conferences as shown below. In each case, compost teas were defined, the results of published work was discussed and the problems and potential of compost teas outlined. This HDC-funded project was introduced and its aims outlined, but no results were presented at any of the seminars, since the audiences were in general not HDC members.

Litterick, A.M. (2004) "Compost Teas - a simple disease control solution". Delivered at a one day seminar entitled "Emerging technologies - composting and using compost". Organised by Imperial College London and Enviros Consulting Ltd., Southwark Cathedral, London on 3 November 2004.

Litterick, A.M. (2004) "Compost Teas - causing a stir in horticulture". Delivered at a Henry Doubleday Research Association Members Conference at Ryton Organic Gardens, Coventry on 12 October 2004.

Litterick, A.M. (2004) "Organic horticultural production". Delivered at the Soil Association Highland Gathering in Inverness on 4/5 June, 2004.

Litterick, A.M. (2004) "Composts and compost teas - can they really help us improve crop health?" Delivered at the Horticultural Development Council/Soft Fruit Growers Association meeting at East Malling on 31 March.

Litterick, A.M. (2004) "Composts and manures - the muck and the magic!" Delivered at the Scottish BioDynamic Agricultural Association Members conference in Stonehaven on 13 March 2004.

Litterick, A.M. (2005) "Organic horticulture – extending the season". Delivered at the Soil Association Seminar in Portree, Isle of Skye on 24th September, 2005.

GLOSSARY

Aerobic - in the presence of oxygen

Anaerobic - in the absence of oxygen

Compost - Solid particulate material that is the result of composting, that has been sanitised and stabilised and that confers beneficial effects when added to soil and/or used in conjunction with plants.

Composting - Process of controlled biological decomposition of biodegradable materials under managed conditions that are predominantly aerobic and that allow the development of thermophilic temperatures as a result of biologically produced heat, in order to achieve compost that is sanitary and stable.

Compost extract - the filtered product of compost mixed with any solvent (usually water), but not fermented. This term has been used in the past to define water extracts prepared using a very wide range of different methods. In the past, the terms “compost extract”, “watery fermented compost extract”, “amended extract”, “compost steepage” and “compost slurry” have all been used to refer to non-aerated fermentations. "Compost extract", "watery fermented compost extract" and "steepages" are approximate synonyms defined as a 1:5 to 1:10 (v:v) ratio of compost to water that is fermented without stirring at room temperature for a defined length of time. "Amended extracts" are compost extracts that have been fermented with the addition of specific nutrients or microorganisms prior to application.

Compost tea - The product of showering or circulating water through compost (or a porous bag of compost suspended over or within an open tank) with the intention of maintaining aerobic conditions. The product of this method has also been termed "aerated compost tea" and "organic tea".

In the past, the term "compost tea" has not always been associated with an aerated fermentation process. It is important to distinguish between compost teas prepared using aerated and non-aerated processes, therefore the terms aerated compost tea (ACT) and non-aerated compost tea (NCT) are used in this review to refer to the two dominant compost fermentation methods. ACT will refer to any method in which the water extract is actively aerated during the fermentation process. NCT will refer to methods where the water extract is not aerated or receives minimal aeration during fermentation apart from during the initial mixing.

Green and wood waste – vegetable waste from gardens and municipal parks, tree cuttings, branches, grass, leaves (with the exception of street sweepings), sawdust, wood chips and other wood waste not treated with heavy metals or organic compounds.

Growing medium - material other than soils *in situ*, in which plants are grown.

Humus - The more or less stable, dark coloured fraction of soil organic matter remaining after the major portions of added plant and animal residues have decomposed.

Manure – Animal excrement which may contain large amounts of bedding.

Maturity - Degree of biodegradation at which compost is not phytotoxic or exerts negligible phytotoxicity in any plant growing situation when used as directed.

Soil fertility - the capacity of the soil to support the crop being grown.

Soil health – the capacity of a specific kind of soil to function as a vital living system within natural or managed ecosystem boundaries, to sustain plant and animal productivity, to maintain or enhance water and air quality, and support human health and habitation.

Soil quality - the capacity of a soil to function within natural or managed ecosystem boundaries, to sustain biological productivity, maintain environmental quality and promote plant and animal health

Stabilisation - Process of biological activities that together with conditions in the composting mass give rise to compost that is stable.

Stable, stabilised, stability - Degree of biodegradation at which the rate of biological activity under conditions favourable for aerobic biodegradation has slowed and microbial respiration will not resurge under altered conditions, such as manipulation of moisture and oxygen levels or temperature.

Vermicompost – The material that is egested from earthworms as casts, then further decomposed and matured in the vermicomposting system. Vermicompost is sometimes used to make compost teas in the USA.

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The Compost Tea Industry Association (2004) http://www.composttea.org

The International Compost Tea Council (2004) http://www.intlctc.org

Appendix I – Methods used to test composts used to make compost teas

Appendix I Table 1. Methods used to test composts used to make compost teas

Parameter/process	Protocol used
Sample preparation for chemical and physical tests, dry matter, bulk density and moisture content	BS EN 13040/2000
pH	BS EN 13037/2000
Electrical conductivity	BS EN 13038/2000
Determination of water extractable elements (including chloride, ammonium-N, nitrate-N, total soluble N, P, K, Mg, Na, B and Mn)	BS EN 13652/2001
% N (total N) and % C (total C) by Dumas method	BS EN 13654-2/2001
Determination of aqua regia extractable elements (including Total P, total K)	BS EN 13650/2001
Organic matter by loss on ignition	BS EN 13039/2000
CO_2 evolution	Original protocol devised by ADAS Consulting Ltd. in WRAP project STA0005 (Annex A.)

Appendix II - details of pesticide applications, compost tea applications and significant dates for Trial 6 (Nursery trials)

Appendix II Table 1. Pesticide applications for *Choisya* ‘Aztec Pearl' (grown from cuttings) and *Cordyline australis* (grown from seed, Trial 6, Hewton Nursery).

Chemical control[a]	Pest/disease/weed	Rate	Trial week	Date	Applied to:
Ronstar 2 Granules	Weed control	20.0g/m^2	35	24 08 04	All plants.
Torq	Citrus mite	0.5 g/1	35	26 08 04	“
Dynamec	Citrus mite	0.25ml/l	38	13 09 04	“
Biological control					
None applied					

Appendix II Table 2. Compost tea application dates for *Choisya* ‘Aztec Pearl' and *Cordyline australis* plants (Trial 6, Hewton Nursery)

Rate of application 5 ml/m^2

Week	Date
36	01 09 04
38	15 09 04
40	29 09 04
42	13 10 05
44	27 10 04
46	10 11 04
48	24 11 04
1	05 01 05
3	19 01 05
5	02 02 05
7	16 02 05
9	02 03 05
11	14 03 05
15	13 04 05
17	27 04 05
19	11 05 05
21	25 05 05
23	09 06 05
25	22 06 05
27	06 07 05
29	20 07 05
31	03 08 05
33	18 08 05

Appendix II Table 3. Trial 6 (Hewton Nursery) significant dates

Task	Date	Comments
Potting	20 08 04	
Trial set up	20 08 04	
Trial completion	20 08 05	
1st Assessment	17 12 04	No major pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
2nd Assessment	24 03 05	No major pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
Disease score		
3rd Assessment	31 05 05	No major pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
Pest incidence		
4th Assessment	01 08 05	No major pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
Plant fresh weight		

Appendix II Table 4. Pesticide applications for *Lavandula* subsp.'Willowbridge calico' plants grown from cuttings) and *Cordyline australis* 'Torbay red' (grown from micropropagated plants, Trial 6, West End Nurseries)

Chemical control[a]	Pest/disease/weed	Rate	Trial week	Date	Applied to:
Frupica	Disease / Botrytis Control	0.8g/l	41	06 10 04	T1Water& T3 Fungicide
Rovral WP	Disease / Botrytis Control	1.0 g/l	43	20 10 04	T1Water& T3 Fungicide
Unicrop Thianosan DG	Disease /Botrytis plus Liverwort and Moss Control	1.0g/l	4	26 01 05	T1Water& T3 Fungicide
Biological control					
None applied					

Appendix II Table 5. Compost tea application dates for *Lavandula* subsp.'Willowbridge calico' and *Cordyline australis* 'Torbay Red'. (Trial 6, West End Nurseries)

Rate of application 5 ml/m^2

Week	Date
35	25 08 04
37	08 09 04
41	06 10 04
43	20 10 04
45	27 10 04
46	10 11 04
48	24 11 04
50	08 12 04
4	26 01 05
5	02 02 05
6	09 02 05
11	14 03 05
15	13 04 05
17	27 04 05
19	11 05 05
21	25 05 05
23	09 06 05
25	22 06 05
27	06 07 05
29	20 07 05
31	03 08 05
33	18 08 05

Appendix II Table 6. Trial 6 (West End Nurseries) significant dates

Task	**Date**	**Comments**
Potting	19 08 04	
Trial set up	19 08 04	
Trial completion	19 08 05	
1st Assessment	16 12 04	No pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
2nd Assessment	24 03 05	No pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
Disease score		
3rd Assessment	01 06 05	No pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
Pest incidence		
4th Assessment	02 08 05	No pests or diseases present.
Plant height		
No. of shoots		
Plant losses		
Plant fresh weight		

Appendix II Table 7. Pesticide applications *for Lavandula stoechas* 'Lavender Lace' and *Phygelius somerford* 'Funfair Orange' (Trial 6, Aline Fairweather)

Chemical control[a]	**Pest/disease**	**Rate**	**Trial week**	**Date**	**Applied to:**
Octave	Botrytis	2.0 g/l	10	08 03 05	Phygelius Treatment T1 and T3
Biological control					
None applied					

[a]Applied as a foliar spray to Treatment 1 plain water and Treatment 3 fungicide

Appendix II Table 8. Compost tea application dates for *Lavandula stoechas* 'Lavender Lace'and *Phygelius somerford* 'Funfair Orange' (Trial 6, Aline Fairweather)

Rate of application 5 ml/m^2

Week	**Date**
34	19 08 04
36	02 09 04
38	16 09 04
40	30 09 04
42	14 10 05
44	28 10 04
48	25 11 04
51	17 12 05
4	27 01 05
8	24 02 05
10	10.03.05
12	24 03 05
14	07 04 05
16	21 04 05
18	05 05 05
20	19 05 05
22	02 06 05
24	16 06 05
26	30 06 05
28	14 07 05
30	28 07 05
32	12 08 05
34	26 08 05

Appendix II Table 9. Trial 6 (Aline Fairweather) Significant dates

Task	Date	Comments
Potting	13.10.04	
Trial set up	13.10.04	
Trial completion	18 08 05	
1st Assessment	15 12 04	No major pests or diseases noted.
Plant height		
No. of shoots		
Plant losses		
2nd Assessment	23 03 05	No major pests or diseases noted.
Plant height		
No. of shoots		
Plant losses		
Disease score		
3rd Assessment	03 06 05	No major pests or diseases noted.
Plant height		
No. of shoots		
Plant losses		
Pest incidence		
4th Assessment	29 07 05	No major pests or diseases noted.
Plant height		
No. of shoots		
Plant losses		
Plant fresh weight		

Appendix II Table 10. Pesticide applications for rose liners (Trial 6, Notcutts)

Chemical control[a]	Pest/disease	Rate	Trial week	Date	Applied to:
Teldor	Botrytis	2 g/l	44	26.10.04	Treatment 3[b]
Rovral WP	Botrytis/powery mildew	1 g/l	49	29.11.04	"
Aliette	Downy mildew	2 g/l	2	17.01.05	"
Teldor	Botrytis	2 g/l	14	31.03.05	"
Mogeton	Liverwort	10 g m^2	20	19.05.05	All plants
Aliette	Downy mildew	2 g/l	25	21.06.05	Treatment 3
Dynamec + Apollo	Two spotted spider mite		30	27.07.05	All plants
Biological control					
Phytoseiulus persimilis	Two spotted spider mite	-	30	27.07.05	All plants
Amblyseius cucumeris	Western flower thrips	-	32	11.08.05	"
P. persimilis	Two spotted spider mite	-	33	18.08.05	"
P. persimilis	Two spotted spider mite	-	35	01.09.05	"
P. persimilis	Two spotted spider mite	-	37	15.09.05	"

[a]Applied as a foliar spray
[b]Treatment 3 was the fungicide programme

Appendix II Table 11. Compost tea application dates for rose liners (Trial 6, Notcutts)

Rate of application 5 ml/m^2

Week	Date
42	11.09.04
44	25.09.04
46	14.10.04
48	28.10.05
50	09.12.04
52	23.12.04
2	13.01.05
4	27.01.05
6	10.02.05
8	24.02.05
10	10.03.05
12	24.03.05
14	07.04.05
16	21.04.05
18	05.05.05
20	19.05.05
22	02.06.05
24	16.06.05
26	30.06.05
28	14.07.05
30	28.07.05
32	12.08.05
34	26.08.05
36	09.09.05
38	23.09.05

Appendix II Table 12. Trial 6 (Notcutts) Significant dates

Task	Date	Comments
Potting	12.10.04	
Trial set up	12.10.04	
Trial completion	29.09.05	
1st Assessment	28.01.05	No pests or diseases apparent
Plant height		
No. of shoots		
Plant losses		
2nd Assessment	26.04.05	No pests apparent, downy mildew present on many plants
Plant height		
No. of shoots		
Plant losses		
Disease score		
3rd Assessment	27.07.05	No diseases apparent, but severe spider mite infestation on many plants
Plant height		
No. of shoots		
Plant losses		
Pest incidence		
4th Assessment	29.09.05	No pests or diseases apparent
Plant height		
No. of shoots		
Plant losses		
Plant fresh weight		

Appendix III - Details of pesticides applied in project

Appendix III Table 1. Details of pesticides applied in project

Product	**Active ingredient**	**Supplier**
Aliette 80WG	80% w/w fosetyl aluminium	Aventis
Apollo 50 SC	clofentezine	Makhteshim
Bavistin DF	50% w/w carbendazim	BASF
Dynamec	abamectin	Syngenta Bioline
Frupica	mepanipyrim	Certis UK
Mogeton	quinoclamine	Certis UK
Ronstar 2G	oxadizon	Certis UK
Rovral WP	iprodione	BASF
Scotts Octave	46% w/w prochloraz	Scotts
Teldor	fenhexamid	Bayer
Torq	fenbutatin oxide	Fargro
Unicrop Thianosan DG	thiram	Unicrop

Appendix IV - Potential financial benefits from using compost teas

There are significant financial benefits to be gained through using compost teas (with limited use of fungicides where required) rather than a full, preventative fungicide programme.) It is difficult to generalise, because different growers use different quantities of fungicide, depending on the crops grown and the production system. However, savings of between 55 and 72 % are typically achieved when growers opt to use compost teas as part of their integrated crop protection programme (based on a reduction in both labour and fungicide costs).

A more detailed appraisal of potential financial benefits is presented in Appendix IV.

Appendix IV Table 1. Cost of time and inputs in a compost tea programme (no fungicides) and standard preventative fungicide programme applied to a 1 ha lavender crop on the same UK nursery in different years.

	Compost tea programme 2004/5	Fungicide programme 2002/3
Inputs*	£451.57	£936.09
Labour @ £8.50/hour	(53 hours) £ 450.55	(285 hours) £2428.56
Total cost (£)	**£902.12**	**£3364.65**

*Inputs include compost, compost tea ingredients and fungicides, where applied. Compost teas and fungicides in both of the above programmes were applied on 21 occasions (alternate weeks throughout the year). Compost teas were applied using the overhead irrigation system. The fungicide programme used 10 approved products in total. Fungicides were applied using conventional pesticide spraying equipment.

It is important to note that compost teas are often applied using the overhead irrigation equipment, as they were in the above case, thus removing the need for applying through conventional spraying equipment. This removes much of the labour (and hence cost) of applying treatments. The savings which a typical compost tea programme brings in comparison with a typical fungicide programme depends on the way in which the compost tea is applied. If compost teas are applied through the irrigation system, the savings are potentially greatest. If compost teas are applied through fungicide spraying equipment, savings in comparison with fungicide programmes are less. The following table shows how the number of hours spent spraying compost teas affect the potential savings made over a typical conventional fungicide programme which uses 10 approved products sprayed singly or in combination once per fortnight. Between 55 and 75 % savings are made when using compost teas.

Appendix IV Table 2. The effect of number of hours spent applying compost teas* on the cost of the compost tea programme (also expressed as % of the cost of a typical preventative fungicide programme applied to the same crop).

Time taken (hrs/ha)	**2.0**	**2.5***	**3.0**	**4.0**	**5.0**	**6.0**
Materials	452	452*	452	452	452	452
Labour	357	446*	535	714	892	1070
Total cost	809	898*	987	1166	1344	1522
% of typical fungicide programme	24	27*	29	35	40	45

*Calculations were based on applications to a 1 ha Lavander crop on a UK nursery.
**As used in HNS 125 Trial 6 at Aline Fairweather