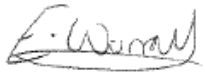
Project title:	Managing ornamental plants sustainably (MOPS)
Project number:	CP 124
Work package title:	Disinfectants
Work package leader:	Dr Erika Wedgwood
Report:	Annual report, December 2015
Previous report:	None
Key staff:	Emma Worrall, ADAS Sam Brown, ADAS
Location of work:	Opperman Plants Ltd., Spalding
Date work commenced:	01 February 2015
Date work completed (or expected completion date):	31 July 2015

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

AUTHENTICATION

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

Emma Worrall
Horticulture Consultant
ADAS



Signature ..... Date 23 December 2015

Report authorised by:

John Atwood
Project Leader
ADAS

Signature Date 26 January 2016

CONTENTS

GROWERS SUMMARY

Headlines

- Re-used carry trays were found to be a source of Fusarium inoculum, and so a potential cause of root diseases
- Hot foam treatment has potential as a disinfectant treatment of floor matting on a nursery for Pythium control, however sequential applications may be required for Fusarium control
- Due to unforeseen circumstances involving unplanned alterations to trial sites, little useful data was generated on the reduction of pathogen transmission to plants from trays and matting following their disinfection

Background and expected deliverables

Good hygiene on a nursery is arguably one of the most important factors for controlling pests and disease effectively. Disinfectants are another useful measure that can be used between crops to help prevent pathogens building up and passing from one crop to another on a nursery. Disinfectants are an essential part of sustainable crop management and can help to reduce the use of plant protection products whilst maintaining a healthy crop.

Different matting types used for standing crops on are a potential source of disease inoculum on a nursery. Carry-trays are another source of disease inoculum as the trays are often reused many times before being discarded. Amongst the wide range of fungal pathogens infecting ornamentals, it is the soil-borne root infecting pathogens that cause the greatest problem resulting from the re-use of plant containers. Soil-borne root infecting pathogens include species from the genera Phytophthora, Pythium, Rhizoctonia, Sclerotinia, Thielaviopsis, Fusarium and Verticillium.

Several different chemical types of disinfectants are currently available for use in horticulture including chlorine-based, iodophors, organic acids, phenols, quaternary ammonium compounds (QAC), peroxyacetic acid and hydrogen peroxide. Some of which have specific recommendations for use in horticulture, others do not. The chemical type of a disinfectant is a key factor determining disinfectant efficacy in different use situations (O'Neill *et al*., 2010). The efficacy of disinfectants is affected by many factors including level of organic matter contamination, nature of the pathogen, survival form of the pathogen, duration of exposure to disinfectant, type of surface, temperature and water pH. Household disinfectants based on natural oils or seed extracts are becoming more widely available as they have some antifungal and antibacterial activity and are generally considered harmless to humans and the environment. However, their level of efficacy in practice, compared with synthetic disinfectants, has not been critically examined against plant pathogens.

Recent changes in legislation have left growers uncertain as to what disinfectant products will be available for ornamental production in the next few years as current products become subject to new biocides legislation.

Specific information about disinfectants is required by growers to be confident that the materials that they might use and the concentration and contact duration of use are capable of doing the job intended on the surfaces presented so that time, money and crop health are not sacrificed.

The objectives for this piece of work were to evaluate the efficacy of disinfectants against Fusarium and Pythium when used on re-used carry-trays and on capillary matting on a commercial ornamentals nursery.

Summary of the work and main conclusions

Methods

There were two parts to this work package; testing the efficacy of disinfectants on re-used carry-trays and testing the efficacy of disinfectants, and also hot foam, on capillary matting for control of Pythium and Fusarium.

Carry-trays

Swabbing was carried out on 11 February 2015, prior to setting up the trial, for subsequent laboratory analysis to determine where best to locate the carry-tray experiment on the nursery.

Fusarium was found on a batch of re-used carry-trays and so these were used for the carry-tray experiment. The swabbing also identified an area on the nursery free from both Pythium and Fusarium which meant the carry-tray experiment could be located in this area. Unfortunately no Pythium was identified in this experiment on the carry-trays.

On 15 June the treatments were applied to the carry-trays. 20 trays with Fusarium present were used for this experiment. The trial consisted of four treatments in total which included three disinfectants and an untreated control (Table 1). A single tray represented a plot and there were five replicates of each treatment. Each tray contained 10 plants.

Disinfectant solutions were made up with tap water to the required label concentration and were applied using a hand-pump sprayer. Tap water was used for the untreated control treatment. Trays were sprayed until they were totally wetted on both surfaces. This was done by placing the five trays in turn on a large volume bin bag. Each tray was sprayed to run-off and placed in a labelled bin bag where it was left for 30 minutes.

The trays were then laid out on the chosen area of the nursery and were set up in a randomised block design. The plan had been for the Easter cacti to be transferred into the carry-trays in their

pots at this stage, however on this date the plants were not ready to be moved and so the cacti were moved into position by nursery staff on the following day, 16 June 2015.

An assessment was due to be carried out two weeks after the treatments had been applied on 1 July 2015 to assess whether there had been any phytotoxic effects from the treatments on the plants and to see whether the trays had been damaged by any of the treatments. An assessment of crop vigour and disease was also due on this date. Unfortunately on arrival at the trial site it was clear that the treated trays had been moved and could not be located.

A repeat assessment of phytotoxicity, vigour and disease were due to be carried out six months after the treatments had been applied but unfortunately without the trays there was nothing else that could be done and so this trial ended on 1 July 2015.

Table 1. Treatment list and application timing for the carry-tray and capillary matting disinfectant experiments

Product name or MOPS code number	Trial	Application timing	Dosage rate (a.i/ha)	Spray volume (L/ha)
1. Untreated	Carry trays and capillary matting	A1	-	-
2. Jet 5	Carry trays and capillary matting	A1	1:125 higher rate for light soiling (80 ml Jet 5 per 10 L water)	5000 L/ha
3. Disolite	Carry trays and capillary matting	A1	2% higher rate for disease control (200 ml in 10 L water)	5000 L/ha
4. Unifect G	Carry trays and capillary matting	A1	4% higher rate for high contamination (400 ml in 10 L water)	5000 L/ha
5. Foamstream	Capillary matting	A1	Standard operation speed	N/A

	Application timing
A1	15 June 2015 prior to moving plants into trays/onto matting

Capillary matting

Swabbing and analysis was also carried out prior to the set up for this part of the experiment, but this time the floor and different types of matting were swabbed, to identify an area with either Pythium or Fusarium present. An area was found where Fusarium was detected on the capillary matting.

Five treatments were used in this experiment which included; the same three disinfectants used in the carry-tray experiment, hot foam and an untreated control. Treatments were applied directly to the matting on 15 June 2015 by hand pump sprayers for the disinfectants and the untreated control. The hot foam treatment was applied by a contractor from Weedingtech on the same day.

The disinfectant matting experiment was arranged as a randomised block design, with five treatments and four replicates per treatment (20 plots). The number of plants in a plot was six, but they were surrounded by a single pot thick guard barrier comprising 14 pots to allow for any lateral movement of disinfestation treatments between plots.

Work carried out in 2014 showed that treatment with hot foam was able to kill Pythium on infested woven ground cover material, but was inconclusive for fusarium. Further work was carried out to test the efficacy of Fusarium mortality with hot foam. Six pieces of Fusarium infested woven ground cover and six infested agar plates were made at ADAS Boxworth and were taken to the nursery on the day of treatment application to be treated with hot foam. A further six pieces of woven ground cover and agar, both infested with Fusarium, were also treated with cold water as the same time, as an untreated control. The woven ground cover material and the infested agar plates were collected and placed on PDA to monitor survival of the Fusarium.

Two weeks after the plants had been stood on the treated capillary matting a phytotoxicity assessment was carried out. The assessment involved examining all six central plants of each plot for phytotoxic effects that might have been caused by any of the treatments. Phytotoxicity scores were recorded on a scale of zero to nine, where zero is a healthy plant similar to the control and nine is a dead plant. A vigour assessment was also carried out two weeks after the plants had been standing on the treated matting. Plants were scored on a scale of one to five where one would indicate very poor vigour and five would mean very strong vigour.

Phytotoxicity and vigour assessments were due to be carried out again at three months after treatment and also at five months after treatment. Disease assessments were also due to be carried out three and five months after treatment. Unfortunately when it came to the three month assessment it was clear that the Easter cacti had been blocked up and so were no longer stood on their correct treatments, therefore only the two week after treatment assessment could be carried out. On the three month assessment on 20 July 2015 this experiment also had to be abandoned.

Results

No treatments were found to cause any phytotoxic effects to the plants following application to the capillary matting and no damage was seen on any of the trays or capillary matting straight after the treatments had been applied, including the hot foam.

From the first vigour assessment from the capillary matting experiment the results showed that the use of disinfectants Unifect G and Disolute and Foamstream on the matting did significantly increase vigour (Table 2).

Table 2. Effect of treatment on crop vigour

Product name or MOPS code	**Mean vigour score**
1. Untreated	6.91
2. Jet 5	7.28
3. Disolite	7.47
4. Unifect G	7.41
5. Foamstream	7.53
F value (df)	0.061
LSD	0.4572

To test the efficacy of hot foam against Fusarium, plates were set up, with both woven ground cover and agar, which had been infested with Fusarium. Treatments were applied on 15 June 2015. Three days after the treatments had been applied, on 18 June 2015, zero out of six pieces of woven ground cover that had been treated with hot foam appeared to have Fusarium present. This differed to the control, cold water treatment, where all six pieces of woven ground cover still had Fusarium present. After 10 days the Fusarium had grown back on four of the six pieces of woven ground cover where hot foam had been applied.

The agar Fusarium infested plates showed the same pattern as the woven ground cover plates with hot foam initially appearing to kill all Fusarium present, so that zero out of the six plates that were treated with hot foam had Fusarium present three days after treatment. However, by 10 days after treatment the Fusarium had grown back on one of the six plates treated with hot foam.

Action Points

- Swabbing used to test for the present of Fusarium and Pythium found re-used carry trays and capillary matting to both be sources of Fusarium highlighting the importance for the use of a disinfection programme.
- The disinfectants used in these experiments were safe for use on carry-trays and capillary matting and caused no phytotoxic effects to Easter cactus where assessments could be carried out (capillary matting experiment).
- The use of two of the disinfectants, Disolute and Unifect G on the matting improved the vigour of Easter Cacti plants subsequently grown on the matting compared to the untreated.
- Hot foam initially appeared to kill Fusarium in the plate tests but the Fusarium had begun to grow back by 10 days after treatment as further resting spores germinate. Although this indicates that a single treatment of hot foam is not an adequate control measure for Fusarium, there may be scope to use a two application procedure with the first application encouraging the resting spores to germinate and then another treatment applied to kill them.

SCIENCE SECTION

Introduction

Effective nursery hygiene, which generally includes a good disinfection programme between crops or batches, is an essential part of sustainable crop management and can lead to a reduction in the use of plant protection products. A “start clean, stay clean” mindset helps to maintain plant quality.

Multicell trays used for seed sowing, cuttings and weaning micro propagated plants have the highest risk factor in their re-use. Seedlings and young plants succumb more easily to infection, usually causing whole-plant death rather than infection of a plant part. The higher humidity conditions needed for seed germination and rooting also favour the spread of fungal mycelium and the germination of spores (AHDB Factsheet 23/02). Amongst the wide range of fungal pathogens infecting ornamentals it is the soil-borne root infecting pathogens that cause the greatest problem in the re-use of containers. Species include those from the genera Phytophthora, Pythium, Rhizoctonia, Sclerotinia, Thielaviopsis, Fusarium and Verticillium.

Several different chemical types of disinfectants are currently available for use in horticulture including chlorine-based, iodophors, organic acids, phenols, quaternary ammonium compounds (QAC), peroxyacetic acid and hydrogen peroxide. Some of which have specific recommendations for use in horticulture, others do not. The chemical type of a disinfectant is a key factor determining disinfectant efficacy in different use situations (O’Neill *et al*., 2010). The efficacy of disinfectants is affected by many factors including level of organic matter contamination, nature of the pathogen, survival form of the pathogen, duration of exposure to disinfectant, type of surface, temperature and water pH. Household disinfectants based on natural oils or seed extracts are becoming more widely available. They have some antifungal and antibacterial activity and are generally considered harmless to humans and the environment. However, their level of efficacy in practice, compared with synthetic disinfectants, has not been thoroughly examined against plant pathogens.

There is also uncertainty as to what disinfectant products will be available to UK growers in the next few years as current products become subject to new biocides legislation. Unlike pesticides, until recently there was no specific requirement for disinfectants to be registered (approved) for a particular use; they were however subject to several pieces of environmental and health and safety legislation. The EU Biocidal Products Directive (BPD), which came into effect in May 2000, initiated a registration requirement but the registration process was slow and few of the disinfectants commonly used in commercial horticulture in the UK were assessed for inclusion. Formaldehyde and dichlorophen were assessed and were not included for common use situations in horticulture (product-type 2). The new EU Biocides Regulation 528/2012, implemented in Britain by the Biocidal Products and Chemicals Regulations (BPCR) 2013, applied from 1 September 2013 when the BPD was revoked. There is a four year transition period for actives not assessed under the BPD to be

submitted for approval at EU level under the EU Biocides Regulation. Product approval will be at national level, undertaken by the HSE in Britain. Actives / products submitted for inclusion and not supported will become unavailable; actives / products not submitted for approval (e.g. due to cost of providing a data registration package) will also become unavailable. Actives already approved under BPD will remain approved under the new Biocides Regulation. Actives used for treating surfaces in commercial horticulture will most probably need to be approved under product-type 2 (disinfectants and algaecides not intended for direct application to humans or animals). The scope for using in commercial horticulture disinfectants with a label recommendation for use in other situations (e.g. veterinary hygiene) will reduce.

Growers need information about disinfectants to be confident that the materials that they might use and the concentration and contact duration use are capable of doing the job intended on the surfaces presented so that time, and that money and crop health are not sacrificed.

The specific objectives for this piece of work were:

• To test the efficacy of three disinfectants on re-used infested plant trays and capillary matting for the control of fungal and/or oomycete root rot infection of plants.

• To evaluate crop safety (phytotoxicity) on a commercial nursery of three disinfection treatments and hot foam.

• To examine treated trays for any adverse effects of the disinfectants on the structure of the trays.

Materials and methods

There were two parts to this work package; testing the efficacy of disinfectants on re-used carry-trays and testing the efficacy of disinfectants, and also hot foam, on capillary matting for controlling Pythium and Fusarium. Both trials were set up on the same commercial nursery in Lincolnshire which was chosen because the nursery was known to have a problem with both Pythium and Fusarium (Table 1).

Pre-experiment swabbing for the detection of plant pathogens on the nursery

Carry-trays

Swabbing was carried out on 11 February 2015, prior to setting up the trial, to determine where best to locate the carry-tray experiment on the nursery. Trays with Fusarium present were required for this experiment, however the floor area where the trays were to be placed needed to be free from Fusarium and Pythium. The swabbing was done by spraying the surface of each carry-tray with sterile water and swabbing the under and upper surfaces once with a clean cotton bud. The cotton bud was then placed into a labelled sterile tube and taken back to the laboratory at ADAS Boxworth. Swabs were taken from a range of tray types and storage locations at the nursery and a note made so that results of the samples could be related back to a particular batch of trays.

In the laboratory each swab was streaked across the surface of a PDA plate and incubated in a 16 hour light: eight hour dark incubator. Plates were examined for the presence of Fusarium and Pythium three days later. Fusarium was present on some of the plates but no Pythium was found so the decision was made to try the baiting method on the nursery to detect this pathogen. Baiting was carried out with both carrot and apple bait bags to test for the presence of Pythium. Prepared baiting bags (similar to a tea bag filled with either carrot or apple) were sent to the grower who placed them on a range of trays and sites on the nursery. On 25 March 2015 the bait bags were returned to ADAS Boxworth where they were plated onto PARP (the standard Pythium selective medium). No Pythium was found on any of the samples returned but an area where no Pythium or Fusarium had been detected was able to be chosen to locate the carry-tray experiment. Carry-trays were chosen from a batch where Fusarium had been detected during the swabbing.

Capillary matting

Swabbing was carried out prior to setting up the trial on 11 February 2015 to determine the best place to locate the disinfectants matting trial on the nursery. This was done by spraying the capillary matting surface with sterile water and then swabbing the matting surface with a clean cotton bud. The cotton bud was then placed into a labelled sterile tube and returned to ADAS Boxworth to be plated up onto PDA using the same methods as were mentioned above. Swabs were taken in a number of glasshouses around the nursery and on a number of beds within these glasshouses.

As before, Fusarium was found on several of the plates but no Pythium was detected. Bait bags were also sent out for the grower to place around the nursery using the method mentioned above to try and detect Pythium, however no Pythium was detected by the baiting technique.

Site and crop details

Table 1. Test site and plot design information

Test location:	Opperman Plants Ltd.	
	Carry-trays	Capillary matting
County	Lincolnshire	Lincolnshire
Postcode	PE11 3EN	PE11 3EN
Soil type/growing medium	Peat based compost	Peat based compost
Nutrition	N/A	N/A
Crop	Cactus	Cactus
Cultivar	Easter cactus	Easter cactus
Glasshouse* or Field	Glasshouse	Glasshouse
Date of planting/potting	16 June 2015 potting	16 June 2015 potting
Pot size	10.5 cm	10. 5 cm
Number of plants per plot	8	6
Trial design (layout in Appendix C)	Randomised block design	Randomised block design
Number of replicates	5	4
Plot size w (m), l (m), total area (m^2)	0.5 X 0.53	0.5 X 0.53
Method of statistical analysis	N/A	ANOVA

*Temperature and relative humidity settings are given in Appendix B

Treatment details

Carry-trays

On 8 May 2015 the trial area was marked out on the nursery and on 15 June the treatments were applied to the carry-trays. Trays were chosen according to where Fusarium had been found during the swabbing mentioned above. 20 trays of the same type and which had been stacked together were chosen to be used. The trial consisted of four treatments in total which included three disinfectants and an untreated control (Table 2). A single tray represented a plot and there were five replicates of each treatment. The tray type chosen held 10 plants in each tray.

Disinfectant solutions were made up with tap water to the required label concentration and were applied using a hand-pump sprayer. Tap water was used for the untreated control treatment. Trays were sprayed until they were totally wetted on both surfaces. This was done by placing the five trays in turn on a large volume bin bag. Each tray was sprayed to run-off and placed in a labelled bin bag where it was left for 30 minutes.

The trays were laid out on an area of the nursery which was identified from the swabbing as being Pythium and Fusarium free. The tray experiment was set up in a randomised block design. The plan had been for the Easter cactus to be transferred into the carry-trays in their pots at this stage, however on this date the plants were not ready to be moved and so the cacti were moved into position by nursery staff on the following day, 16 June 2015.

Capillary matting

On 8 May 2015 the trial site was marked out on an area of the nursery which was chosen because Fusarium had been found on the capillary matting. The presence of Fusarium was required for this part of the trial. Five treatments were used in this experiment which included three disinfectants, hot foam and an untreated control (Table 2). Treatments were applied directly to the matting on 15 June 2015 which was done by hand-pump sprayers for the disinfectants and the untreated control. The hot foam treatment was applied by a contractor from Weedingtech on the same day.

The disinfectant matting experiment was arranged as a randomised block design, with five treatments and four replicates per treatment (20 plots). There were six plants per plot but they were surrounded by a single pot thick guard barrier comprising 14 plants to allow for any lateral movement of disinfestation treatments between plots.

An extra test was carried out to test the efficacy of Fusarium mortality with hot foam. Six pieces of Fusarium infested woven ground cover and six infested agar plates were made at ADAS Boxworth and were taken to the nursery on the day of treatment application to be treated with hot foam. A further six pieces of woven ground cover and agar, both infested with Fusarium, were also treated with cold water as the same time, as an untreated control. The woven ground cover material and the infested agar plates were collected and placed on PDA to monitor survival of the Fusarium.

Table 2. Treatments

Product name or MOPS code number	Trial	Application timing	Dosage rate (a.i/ha)	Spray volume (L/ha)
1. Untreated	Carry-trays and capillary matting	A1	-	-
2. Jet 5	Carry-trays and capillary matting	A1	1:125 higher rate for light soiling (80 ml Jet 5 per 10 L water)	5000 L/ha
3. Disolite	Carry-trays and capillary matting	A1	2% higher rate for disease control (200 ml in 10 L water)	5000 L/ha
4. Unifect G	Carry-trays and capillary matting	A1	4% higher rate for high contamination (400 ml in 10 L water)	5000 L/ha
5. Foamstream	Capillary matting	A1	Standard operation speed	N/A

	Application timing
A1	15 June 2015 prior to moving plants into trays/ onto matting

Table 3. Application details

Application No.	**A1**
Application date	15 June 2015
Time of day	11:00
Application method	Hand-pump sprayer
Temperature of air – max/min (°C)	22°C/ 18°C
Relative humidity (%)	61.5
Cloud cover (%)	N/A
Crop growth stage	N/A
Crop comments	-
Other*:	-

*Includes soil temperature and moisture details where relevant

Target pest(s)

Table 4. Target pest(s)

Common name	**Scientific Name**	**Infection level pre-application**
Fusarium	*Fusarium oxysporum*	Present

Assessments

Carry-trays

An assessment was due to be carried out two weeks after the treatments had been applied on 1 July 2015 to assess to see whether there had been any phytotoxic effects from the treatments on the plants and to see whether the trays had been damaged by any of the treatments. An assessment of crop vigour and disease was also due on this date. Unfortunately on arrival at the trial site it was clear that the treated trays had been moved and could not be located.

Repeat assessment of phytotoxicity, vigour and disease were due to be carried out six months after the treatments had been applied but unfortunately without the trays there was nothing else that could be done and so this trial ended on 1 July 2015.

Capillary matting

Two weeks after the plants had been stood on the treated capillary matting a phytotoxicity assessment was carried out. The assessment involved examining all six central plants of each plot for phytotoxic effects that might have been caused by any of the treatments. Phytotoxicity scores were recorded on a scale of zero to nine, where zero is a healthy plant similar to the control and nine is a dead plant. A vigour assessment was also carried out two weeks after the plants had been standing on the treated matting. Plants were scored on a scale of one to five where one would indicate very poor vigour and five would mean very strong vigour.

Phytotoxicity and vigour assessments were due to be carried out again at three months after treatment and also at five months after treatment. Disease assessments were also due to be carried out on these dates.

Unfortunately when it came to the three month assessment it was clear that all the Easter cacti had been blocked up and so were no longer stood on their correct treatments, therefore only the two week after treatment assessment could be carried out for this trial. On the three month assessment date, on 20 July 2015, this experiment also had to be abandoned.

Table 5. Assessments

Assessment No.	Date	Growth stage	Timing of assessment relative to last application	Assessment type(s) (e.g. no./% LAI/crop safety)
1	20 July 2015	1 leaf above ground per shoot x 5 shoots per pot	2 weeks after plants had been stood on their treatments	Phytotoxicity and vigor

Results

Crop vigour

Capillary matting

Crop vigour was significantly improved by some disinfectant treatments at the first assessment, two weeks after the plants had been stood on their treatment (Table 6). The untreated cacti had the lowest mean vigour score which differed significantly to Disolite, Unifect G and Foamstream treated crops. The crops that had been stood on an area treated by Jet 5 had a higher mean score of vigour than the untreated control but this difference was not significant.

Table 6. Effect of treatments on crop vigour (capillary matting experiment)

Product name or MOPS code	**Mean vigour score**
1. Untreated	6.91
2. Jet 5	7.28
3. Disolite	7.47
4. Unifect G	7.41
5. Foamstream	7.53
F value (df)	0.061
LSD	0.4572

Crop damage

Capillary matting

No phytotoxic damage from any of the treatments was seen on any of the cacti two weeks after the plants had been standing on their treated plots of capillary matting (Table 8).

Table 8. Effect of treatments – crop damage (capillary matting experiment)

Product name or MOPS code	Mean phytotoxicity score
1. Untreated	0.0
2. Jet 5	0.0
3. Disolite	0.0
4. Unifect G	0.0
5. Foamstream	0.0
F value (df)	NS
LSD	-

Efficacy of hot foam against Fusarium

To test the efficacy of hot foam against Fusarium, plates were set up, with both woven ground cover and agar, which had been infested with Fusarium. Treatments were applied on 15 June 2015. Three days after the treatments had been applied, on 18 June 2015, zero out of six pieces of woven ground cover that had been treated with hot foam appeared to have Fusarium present (Figure 1). This differed to the control, cold water treatment, where all six pieces of woven ground cover still had Fusarium present. After 10 days the Fusarium had grown back on four of the six pieces of woven ground cover where hot foam had been applied.

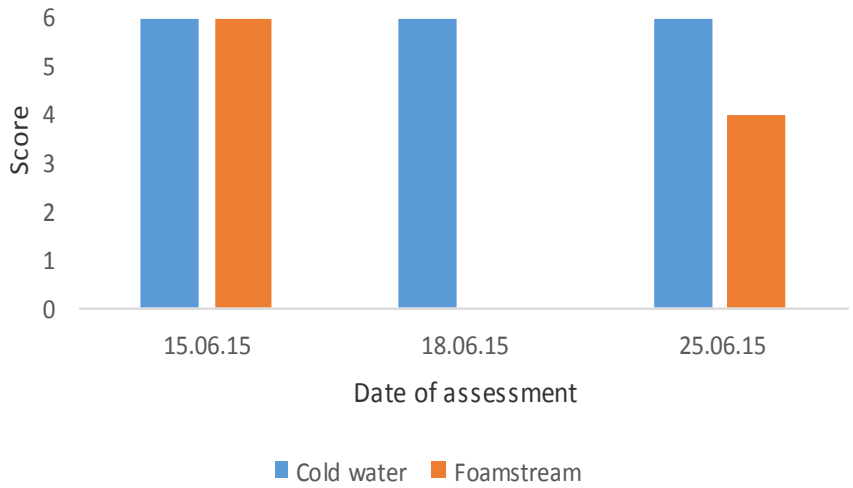


Figure 1. Survival of Fusarium on woven ground cover after being treated with hot foam

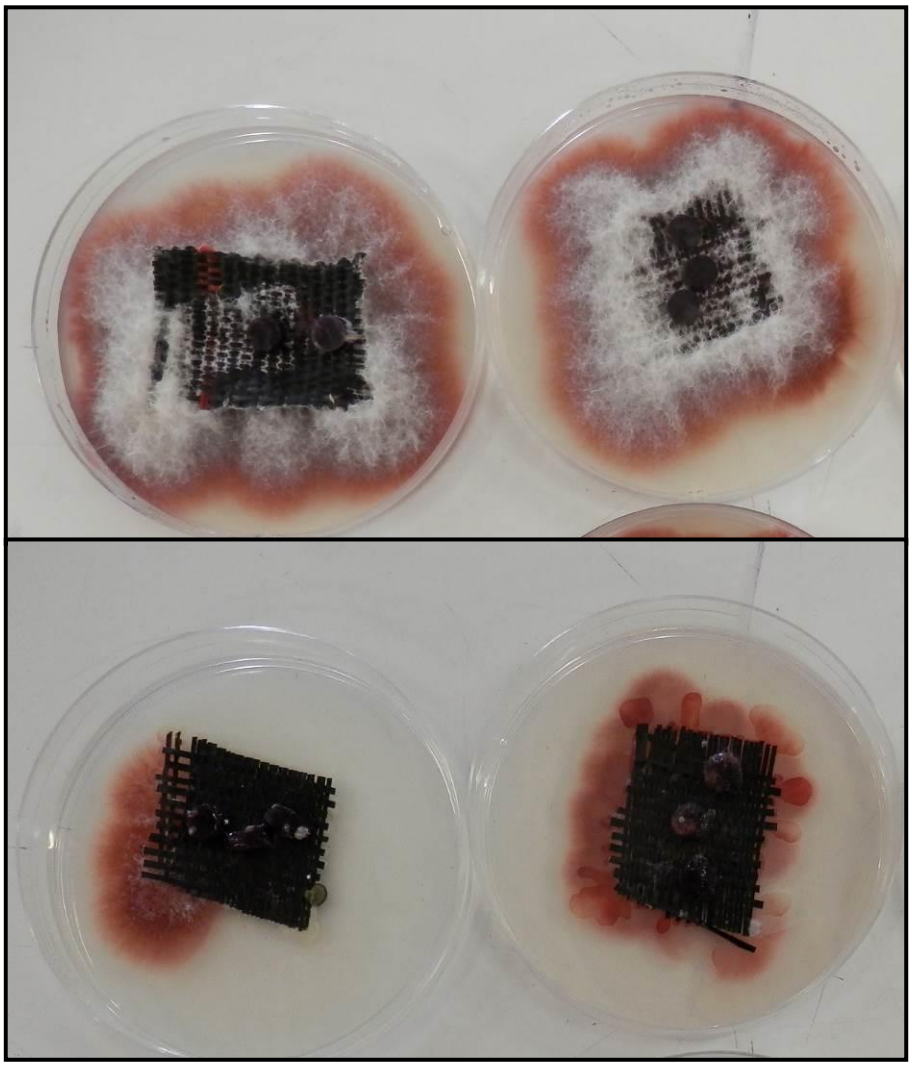


Figure 2. Pieces of woven ground material contaminated with Fusarium after removal to agar culture plates following treatment, showing two of the six pieces per treatment. Cold water (Top) and Foamstream treated material (Bottom). All four plates show growth of Fusarium after incubation for 10 days, but the plates treated by Foamstream show substantially slower growth.

The agar Fusarium infested plates showed a similar pattern as the woven ground cover plates with hot foam initially appearing to kill all Fusarium present, so that zero out of the six plates that were treated with hot foam had Fusarium present three days after treatment (Figure 2). However, by 10 days after treatment the Fusarium had grown back on one of the six plates treated with hot foam.

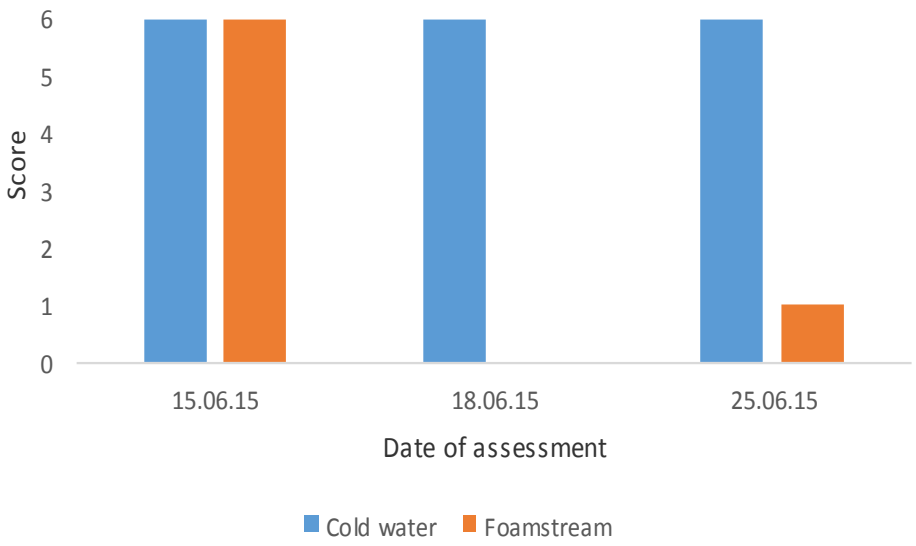


Figure 3. Survival of Fusarium on agar plates after being treated with Foamstream hot foam

Formulations

Observations were made of ease of mixing of the formulations and for any conspicuous problems associated with nozzle blockages or uneven spray pattern during mixing and application. No problems were encountered during mixing or application of any of the product formulations under test.

Discussion

No Pythium was found on this nursery throughout this trial using either the swabbing technique or the baiting technique, however both these techniques found Fusarium to be present on both capillary matting and on re-used carry-trays. This highlights the need for an effective disinfectant product to be used between crops to prevent the spread of these fungal pathogens to help prevent disease from developing. The use of a disinfectant can also help a grower to reduce the number of pesticides used later on, helping the grower to achieve a more sustainable production of crops.

None of the treatments used in this trial caused any damage to either the capillary floor where they were applied or to the carry-trays that they were applied to and so Jet 5, Disolite and Unifect G can be considered safe to apply to these materials. The hot foam caused no damage when applied to the capillary matting, however it was not applied to carry trays as in the previous year's experiment the use of hot foam caused plastic materials to warp. It is not advisable to use hot foam on any plastic based materials such as carry-trays.

Unfortunately no data could be obtained from the carry-tray experiment and so it is not certain whether standing a plant in a carry-tray that has been treated by any of the disinfectants used in this trial would cause any phytotoxicity to the plant or not. No phytotoxic damage was seen on any

of the cacti that had been stood on Jet 5, Disolite, Unifect G or hot foam on the capillary matting, although it must be noted that the plants were not moved immediately onto the capillary matting after the treatments had been applied and the time lag could have reduced the likelihood of phytotoxic damage to the plants.

Crop vigour was found to be significantly improved when the capillary matting had been treated with either Disolite, Unifect G or hot foam compared to the untreated control crop vigour. This could suggest that these treatments had prevented early stages of pathogen infection which could have been caused by Fusarium, although there could be other factors involved that were not investigated as part of this trial. Plants treated with Jet 5 did have higher vigour scores than the untreated but these weren't significantly different to the untreated crop.

In the extra experiment set up to test the efficacy of hot foam on Fusarium the results showed that the hot foam initially appears to kill Fusarium, however it also appears to trigger resting spores to germinate shortly after the hot foam has been applied. These results suggest that an initial treatments of hot foam could be used to treat Fusarium mycelium and cause these resting spores to germinate and this could then be followed up with a second application or another disinfectant to then kill these newly germinated spores.

Conclusions

All treatments tested in this trial could potentially be used on nurseries to treat floor matting or carry-trays to kill root disease causing pathogens, however not enough data was collected from this trial to support the efficacy of these treatments. Further data would also be required on the safety of these treatments when applied to floor matting or re-used carry trays to different crops. If these treatments were found to be effective and safe then there is a high possibility that they could offer another tool for growers to use to prevent infection from root causing diseases on the nursery.

References

O'Neill, T.M., Locke, T. and Dyer, C.J. (2010). A comparison of four pre-plant soil treatments for control of Verticillium wilt in field grown trees. *Acta Horticulturae* 883:235-242.

Wedgwood, E. F., 2014. *Hot foam treatment for the control of pathogens in debris and on re-used propagation trays.* AHDB. Available at: <http://horticulture.ahdb.org.uk/sites/default/files/research_papers/CP%20124_Report_Year%201_Pathology_Foamstream.pdf> [Accessed 9 December 2015].

Appendix A – Study conduct

ADAS is officially recognised by United Kingdom Chemical Regulations Directorate as competent to carry out efficacy testing. The experiments reported were carried out according the internal ADAS operating procedures

GLP compliance will not be claimed in respect of this study.

Relevant EPPO/CEB guideline(s)		**Variation from EPPO**
PP 1/152(3)	Design and analysis of efficacy evaluation trials	PP 1/152(3)
PP 1/135(3)	Phytotoxicity assessment	PP 1/135(3)
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including GEP	PP 1/181(3)

There were no significant deviations from the EPPO and national guidelines.

Appendix B – Meteorological data

Location of the weather station	Cambridge
Distance to the trial site	54 miles
Origin of the weather data	Weather station for long term average Data logger for average conditions during the trial

Long-term averages from Cambridge			
Month/period	**Min temp (ºC)**	**Max temp (ºC)**	**Rainfall (mm)**
February	1.2	7.4	30.8
March	3.1	11.1	19.4
April	4.1	15.0	20.2
May	7.5	16.5	48.8
June	9.5	20.3	19.0
July	12.3	22.5	78.8
August	12.7	22.2	47.4

Average conditions during the trial:

Month/period	**Av temp (ºC)**	**Min temp (ºC)**	**Max temp (ºC)**	**Av RH (%)***	**Rainfall (mm)**
June	22.6°C	18.0 °C	27.0°C	75.56%	N/A
July	23.9°C	16.0°C	33.5°C	79.62%	N/A
August	22.6°C	14.5°C	30.5°C	84.36%	N/A

***protected crops only**

Weather at treatment application:

Month/period	**Min temp (ºC)**	**Max temp (ºC)**	**Rainfall (mm)**
15 June 2015	18.0°C	18.5°C	N/A

Appendix C – Agronomic details

Growing system

Crop	Cultivar	Planting/sowing date	Row width (m) or pot spacing
Cactus	Easter cactus	End June 2015	In trays

Other pesticides - active ingredient(s) / fertiliser(s) applied to the trial area

Date	Product
July	Conserve (insecticide)

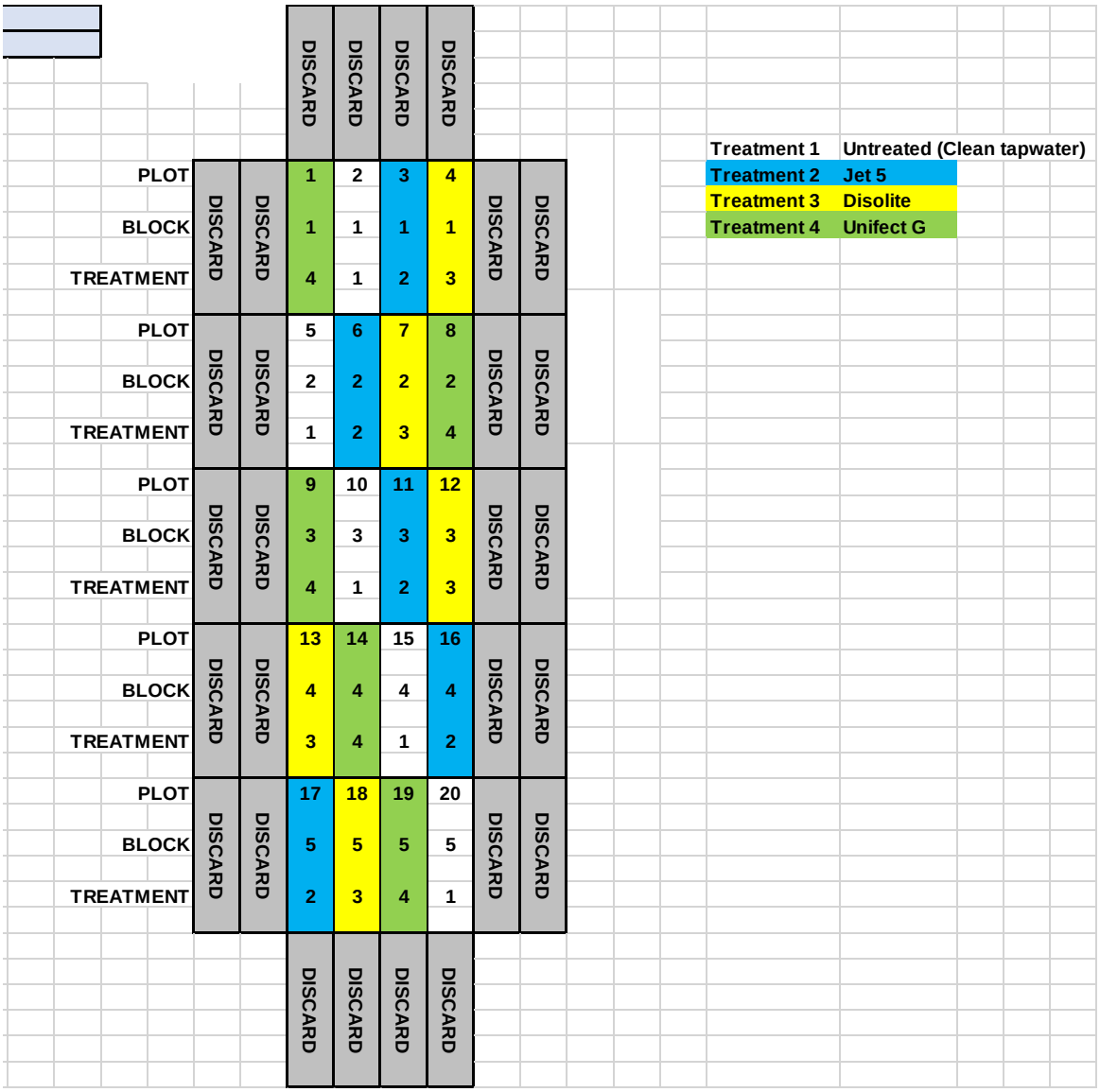
Details of irrigation regime (pot-grown crops)

Type of irrigation system employed (e.g. overhead sprinkler, hand watering, drip, ebb and flow, capillary sandbed or capillary matting)
Overhead sprinkler

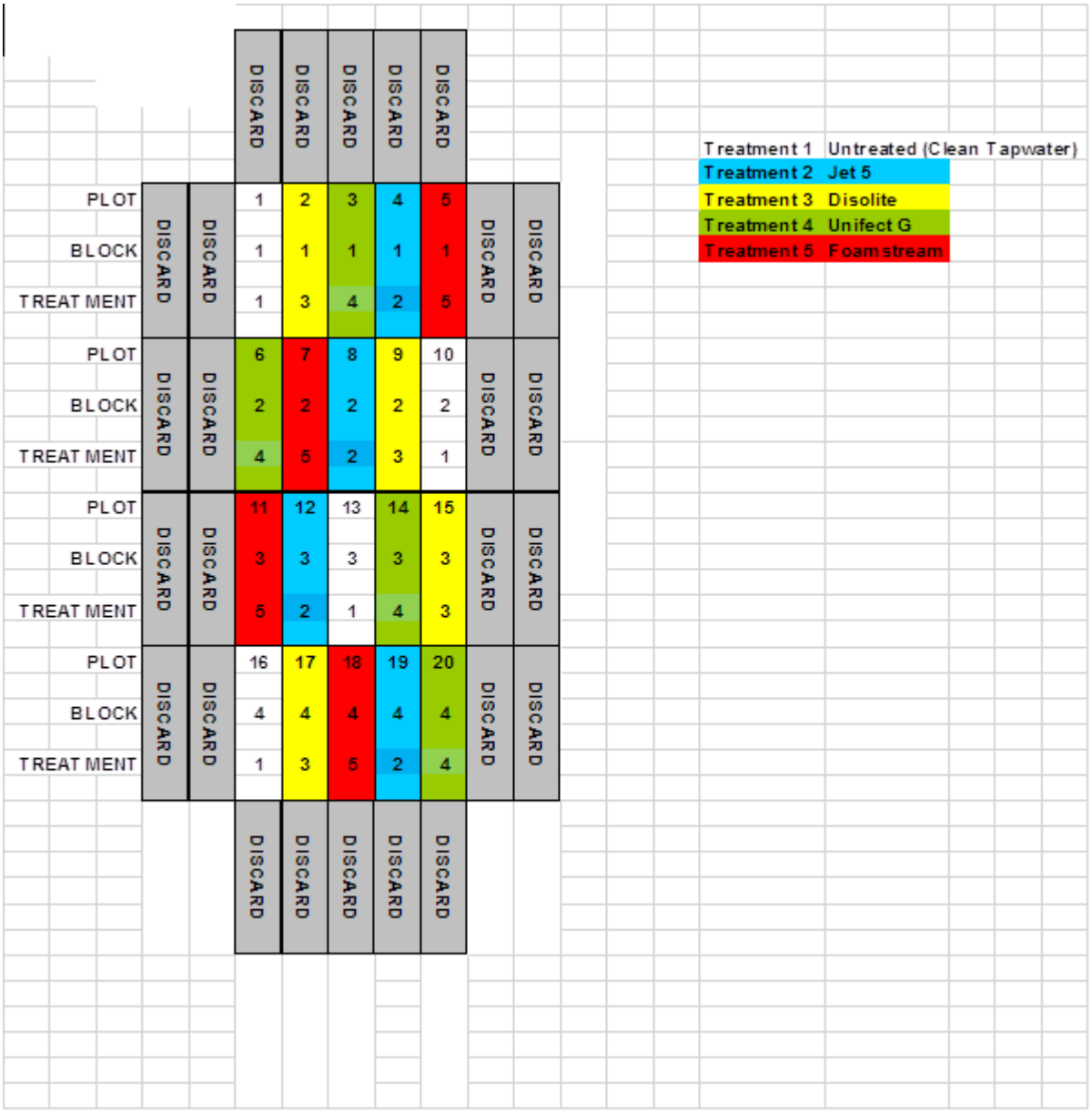
Date	Type, rate and duration
July	Overhead irrigation carried out twice a week

Appendix D – *Trial layout*

Arrangement proposed for disinfested carry-trays



Arrangement in glasshouse of disinfestation treatments to capillary matting



Appendix E – Copy of the Certificate of Official Recognition of Efficacy Testing Facility or Organisation

Certificate of

Official Recognition of Efficacy Testing Facilities or Organisations in the United Kingdom

This certifies that

ADAS UK Limited

complies with the minimum standards laid down in Regulation (EC) 1107/2009 for efficacy testing.

The above Facility/Organisation has been officially recognised as being competent to carry out efficacy trials/tests in the United Kingdom in the following categories:

Agriculture/Horticulture
Stored Crops
Biologicals and Semiochemicals

Date of issue: 10 May 2013
Effective date: 18 March 2013
Expiry date: 17 March 2018

Certification Number
ORETO 339

Signature _____
Authorised signatory

HSE
Chemicals Regulation Directorate

Department of Agriculture and Rural Development

Appendix F – *Photographs*

Figure 1. Carry-trays being treated with one of the disinfectant treatments, for use in trial

Figure 2. Easter cactus on matting two weeks after disinfection treatments

Figure 3. Layout of randomised blocks of plots of cactus pots on disinfested matting

Figure 4. Setting up the capillary matting trial using frames to position the pots

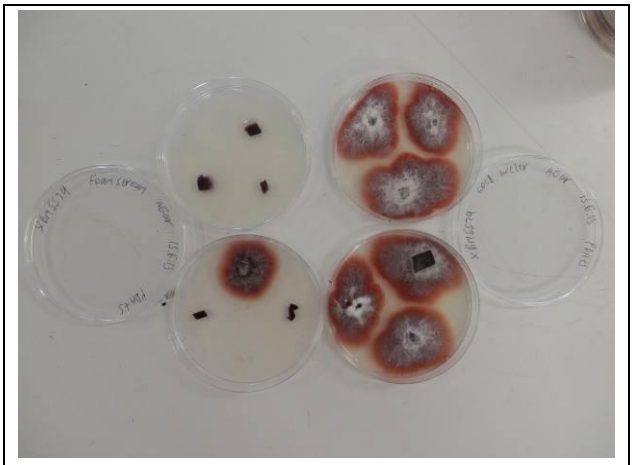


Figure 5. Fusarium mycelium on agar treated with hot foam (left) and cold water (right) following incubation on agar for 10 days