Project title:	Evaluation of the non-metalaxyl-M based fungicides/programmes against metalaxyl-M resistant strains of *Plasmopara obducens*
Project number:	PO 012
Project leader:	Dr Philip Jennings The Food and Environment Research Agency, Sand Hutton, York, YO41 1LZ
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Key staff:	Gilli Thorp, Dr Stephane Pietravale (Fera) Dr Martin McPherson, James Townsend, Matthew Goodson*, Cathryn Lambourne* (STC) * Left during 2013
Location of project:	Fera, York STC, Cawood
Industry Representative:	Mr Mike Smith W D Smith and Son, Grange Nurseries Mr Russell Woodcock Bordon Hill Nurseries Ltd.
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The results and conclusions in this report are based on an investigation conducted over an 11 month 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.

[Name]
[Position]
[Organisation]

Signature ..... Date .....

[Name]
[Position]
[Organisation]

Signature ..... Date .....

Report authorised by:

[Name]
[Position]
[Organisation]

Signature ..... Date .....

[Name]
[Position]
[Organisation]

Signature ..... Date .....

CONTENTS

GROWER SUMMARY

Headline

Fungicides programmes are available which confer good, although not complete control of the metalaxyl-M resistant strain of *Plasmopara obducens*.

Background

Downy mildew of impatiens caused by *Plasmopara obducens* was first reported in the UK in June 2003 and caused considerable economic damage to commercial crops and municipal plantings, especially, though not exclusively, in the South of England. Initially emergency statutory action was taken by the Plant Health and Seeds Inspectorate (PHSI) and the downy mildew pathogen on impatiens was declared notifiable. This was revoked in 2005 on the proviso that the industry took on responsibility for management of the disease through implementation of an industry code of practice (Good Horticultural Practice (GHP). Between 2004 and 2006, the disease was not reported in commercial crops but reappeared at low to moderate levels in 2007. In the following year (2008) the disease was once again quite widespread and damaging, especially in municipal and other outdoor plantings. In 2011, early and widespread outbreaks were reported in vegetative cutting raised material and due to a lack of fungicidal control (related to the introduction of a metalaxyl-M resistant strain) the infection soon spread to seed raised crops with devastating impacts on UK production.

Work in the HDC funded projects (PC 230, PC 230a and PC 230b) has contributed to a greater understanding of the disease and has provided guidance to help minimise outbreaks (e.g. HDC briefing notes issued in 2011 and updated in 2012). It was clear from this work that spray programmes which included metalaxyl-M were the most effective against the disease. With the discovery of resistance to this active ingredient late in 2011, production of susceptible *Impatiens walleriana* in the UK fell dramatically and this, to some extent, has taken the pressure off. However, where growers have continued to offer this bedding plant species, growers and their advisers now have to make educated guesses on suitable spray programmes. The work aims to provide fungicide efficacy data against the metalaxyl-M resistant strain to assist growers in making informed decisions on suitable fungicide programmes, helping to minimise spread where infections arise.

Summary

Fungicide efficacy

Initially thirteen fungicides were examined in laboratory-scale efficacy tests. These were applied as protectant treatments as both spray and soil applications. Efficacy tests were carried out on six week old impatiens ('DeZire White'), using a metalaxyl-M resistant isolate of *P. obducens*. The results indicated that a number of products, with differing modes of action, gave effective control of the metalaxyl-M resistant strain of *P. obducens* particularly when applied as a spray treatment. These included Fenomenal (fosetyl aluminium + fenamidone), Revus (mandipropamid), Paraat (dimethomorph) and a coded product HDC F33. The number of fungicides showing control of the metalaxyl-M resistant strain was encouraging, as this meant that spray programmes could be identified which did not rely on a single mode of action or active ingredient.

The initial laboratory scale tests were followed up with a semi-commercial scale trial using impatiens 'DeZire White' grown in six-packs inoculated with the metalaxyl-M resistant strain of *P. obducens*. Twelve treatment programmes were examined which included a 'standard programme' (Proplant (propamocarb-HCL), Fubol Gold (mancozeb and metalaxyl-M) and Previcur Energy (fosetyl aluminium + propamocarb HCL), seven individual products applied as either a two or four foliar spray programme, a soil incorporation treatment and three experimental treatments applied as either two, three or four spray programmes. All plants were inoculated with a metalaxyl-M resistant strain of *P. obducens* after at least one treatment of a programme had been applied. Three disease assessments were carried out two, four and six weeks after inoculation. Most programmes trialled gave a significant reduction in downy mildew symptoms by the first assessment. By the final assessment the standard programme (which included metalaxyl-M as the second application) and the two treatment single product programmes, other than where Paraat or Revus had been applied, failed to control the disease. Where a four treatment single product programme was used it always provided better disease control than an equivalent two treatment programme. Overall, the programmes which gave the greatest reduction in disease were the four treatment Revus programme and experimental programme 2 which had Fenomenal, Paraat and Revus in the programme. Even the best performing programmes succumbed to the disease with almost all plants showing signs of disease, however, plants had been inoculated with a high spore concentration and severe disease pressure was maintained throughout the experiment, which meant that programmes were tested under inoculum loads which would not necessarily occur commercially.

From the trials carried out here programmes containing Paraat and Revus, both of which are already approved for use on protected ornamentals, offer the greatest potential for controlling the metalaxyl-M resistant strain of *P. obducens*. Programmes including Fenomenal and HDC F33 in addition to Paraat and Revus also showed potential; though HDC F33 cannot be used commercially until such time products based on this experimental active can be approved.

Crop Safety

Twelve fungicides were examined in crop safety trials on seedlings from the impatiens series 'DeZire' and 'Accent'; white, red, lavender (for 'DeZire') and lilac (for 'Accent') varieties were tested for both series. Seedlings were tested against full and half rate applications of each treatment, with assessments of phytotoxicity and the number of deformed seedlings for each series and colour made. The first assessment identified some plant deformities, however, these seemed to relate to the impatiens series or colour rather than the chemical treatment as there was no difference in the level of deformity between control or treated plants. No other signs of phytotoxicity were observed. Following the second assessment differences between treatment and control plants were only noticed for the impatiens from the 'Accent' series following treatment with Fubol Gold (mancozeb and metalaxyl-M) where there appeared to be a higher number of deformed or blind plants.

Financial Benefits

In the UK, the annual retail value of the impatiens crop has previously been estimated to be ca. £40m. The introduction of *Plasmopara obducens* and particularly the development of a metalaxyl-M resistant strain in 2011 demonstrated how a breakdown in disease control has the potential to almost completely destroy annual production as well as undermine consumer confidence in this commercially important product. The current value of the UK impatiens crop is not currently known but it is anticipated to be significantly lower than previous estimates suggest.

Establishing the suitability of fungicide programmes to control the newly introduced metalaxyl-M resistant strain of impatiens downy mildew will ensure growers have available to them (subject to product approval) the most effective currently available fungicides and spray programmes to minimise losses that may result from any future outbreaks. The control of both strains of *Plasmopara obducens* during production is essential if the UK market for impatiens is ever to recover.

Action Points

- To minimise the introduction of downy mildew on the nursery use only seed-raised impatiens and avoid importing vegetative cuttings that have been shown previously to carry a high risk factor in terms of downy mildew, including resistance, infection.
- As far as possible grow impatiens as outlined in the HDC guide for ‘Good Horticultural Practice for the Prevention and Control of Impatiens Downy Mildew’, and the HDC Factsheet 11/09 ‘Impatiens Downy Mildew’.
- Ensure that spray programmes do not rely on a single mode of action or active ingredient. Such alternation with fungicide programmes will reduce the risk of further resistant populations developing.
- Have downy mildew infected impatiens tested to identify the metalaxyl-M sensitivity of the infecting pathogen.

SCIENCE SECTION

Introduction

Downy mildew of impatiens caused by *Plasmopara obducens* was first reported in the UK in June 2003 (McPherson, pers com) and caused considerable economic damage to commercial crops and municipal plantings, especially, though not exclusively, in the South of England. Initially emergency statutory action was taken by the Plant Health & Seeds Inspectorate (PHSI) under Article 22 of the Plant Health Order 1993 and the downy mildew pathogen on impatiens was declared notifiable. This emergency legislation required the industry to notify PHSI of any suspect cases of the disease and, where the pathogen was confirmed, statutory action was taken to destroy the infected plants and to quarantine (for a pre-determined time period) the remaining apparently disease-free stock. If the pathogen was subsequently found to have spread to adjacent stock this would also be destroyed. This action was revoked in 2005 on the proviso that the industry took on responsibility for management of the disease through implementation of an industry code of practice (Good Horticultural Practice (GHP). Between 2004 and 2006, the disease was not reported in commercial crops but reappeared at low to moderate levels in 2007. In 2008, the disease was once again quite widespread and damaging, especially in municipal & other outdoor plantings. In 2011 early outbreaks originating from imported cutting raised material but spreading to seed raised crops proved difficult to control due to the emergence of metalaxyl-M resistance and resulted in devastating impacts on the UK production.

In the scientific literature *P. obducens* is reported to occur in North America and parts of Asia and Europe, including Denmark, Finland, the Netherlands, Germany, the Czech Republic and Lithuania in the EU and Romania and Russia in the rest of the EPPO region. In reality, the disease was much more widespread and in 2008, also caused problems in South Africa, Australia and Japan. Following the 2011 outbreak a survey was carried out with HDC funding (PO 011) which examined the distribution of *P. obducens* in the UK, this found that the disease was widely distributed across England and that the metalaxyl-M resistance seen in 2011 was, perhaps surprisingly, not encountered.

Work in the HDC funded projects (PC 230, PC 230a and PC 230b) has contributed to a greater understanding of the disease and hence provided guidance for minimising outbreaks (e.g. HDC briefing notes issued in 2011 and updated in 2012). It was clear from this work that spray programmes which included metalaxyl-M were the most effective against the disease. However, the discovery of resistance to this active ingredient in 2011

meant that ensuring effective control had suddenly become more difficult and growers had to formulate alternative spray programmes without sufficient knowledge of the relative performance of alternative mode of action products. Provision of such comparative fungicide efficacy data against the metalaxyl-M strain would assist growers in making informed decisions on suitable action against outbreaks, helping to minimise spread where infections arise. With this in mind the objectives of the project were to,

a) Evaluate the efficacy of fungicides (small-scale pot trials), previously shown to have activity against downy mildew of impatiens (excluding those containing metalaxyl-M), to the metalaxyl-M resistant strain isolated in 2011.
b) Evaluate fungicide programmes (not containing metalaxyl-M) in large-scale 'commercial' trials for efficacy against the metalaxyl-M resistant strain of *P. obducens*.
c) Evaluate the safety of fungicides & programmes for use on impatiens seedlings.

Materials and methods

Fungicide efficacy testing - small scale

Thirteen products (Table 1) were tested in a small scale glasshouse test to determine fungicide efficacy against a metalaxyl-M resistant isolate of *Plasmopara obducens* collected during 2011.

Products were applied as sprays, drenches or incorporated into the soil at the manufacturer's recommended rate (Table 1), with all sprays applied in a spray volume equivalent to 1000L water/ha. Spray and drench treatments were applied at a single timing three days pre-infection, whereas the soil incorporation treatment was applied 12 days pre-infection.

For each treatment, three replicate impatiens plants (4 weeks old) were inoculated to run-off with a sporangial suspension of the metalaxyl-M resistant isolate and incubated for approximately 18hrs in the dark at 5°C. Plants were then transferred to a glasshouse and maintained at a constant 20°C, with 12hr day period and grown on for 8-10 days. Prior to disease assessment the upper leaf surface of all plants was wetted overnight to allow sporangial formation on the underside of the leaf. For each treatment the number of sporulating leaves were counted and compared to the untreated control plants.

Fungicide programme testing

The initial laboratory scale tests were followed up with a semi-commercial scale trial to establish the efficacy of fungicide programmes for the control of a metalaxyl-M resistant isolate of *P. obducens*. The trial diary is presented in appendix I.

Impatiens (variety 'DeZire White'), which had received a post-sowing application of propamocarb hydrochloride, were sourced from a commercial nursery on 17/04/13. These seedlings were further treated with mancozeb (as Karamate) on 22/04/13 to ensure the plants remained free from downy mildew until the start of the trial. As mancozeb acts as a contact fungicide it was felt that this treatment would not impact on establishment later in the trial. Plants were potted into 6-packs on 30/04/13.

Eleven fungicides (Table 1) were highlighted for use in 13 programmes. These included a standard programme (Proplant (propamocarb hydrochloride), Fubol Gold (mancozeb and metalaxyl-M) and Previcur Energy (fosetyl-aluminium and propamocarb hydrochloride), seven individual products applied as foliar sprays either twice or four times, a soil incorporation treatment and three experimental spray programmes with either two, three or four application timings (Table 2). Each programme plot consisted of four six-packs of impatiens (24 plants in total). The plots for the single product programmes were split in two, with half (12 plants) treated with a two spray programme and the other half with a four spray programme. The trial was replicated four times and laid out in a fully randomized block design (Appendix I). The first treatment in each programme was applied 3 days after potting, subsequent treatments were applied at 7 to 14 day intervals depending on the programme (Table 2). The exception to this was HDC F64, where the soil incorporation applied at potting and no further applied treatment.

Table 1. Products and application rates used in the small-scale glasshouse tests and semi commercial scale programme trial.

Product (active ingredient)	Trial used in	Application method	Application rate
Fenomenal (fosetyl aluminium (600g kg^{-1}) + fenamidone (60g kg^{-1}))	Small scale	Spray*	4.5 kg/ha
		Drench	100 g/100 L @ 3 L/m^2 = 30 kg/ha
	Programme	Spray**	4.5 kg/ha
Previcur Energy (propamocarb-HCL (530 g L^{-1}) + fosetyl aluminium (310 g L^{-1}))	Small scale	Spray*	2.5 L/ha
		Drench	3 ml product/m^2 @ 3 L/m^2
	Programme	Spray**	2.5 L/ha
Revus (mandipropamid (250 g L^{-1}))	Small scale	Spray	0.6 L/ha
	Programme	Spray*	0.6 L/ha
HortiPhyte (potassium phosphate)	Small scale	Spray*	1 L/ha
		Drench	1 ml product/m2 @ 2 L/m^2
Paraat (dimethomorph (500 g kg^{-1}))	Small scale	Spray*	3 kg/ha
		Drench	0.14 g/L @ 10% of pot vol
	Programme	Spray**	3 kg/ha
Karamate (mancozeb (750 g kg^{-1}))	Small scale	Spray*	2 kg/ha
Signum (boscalid (267 g kg^{-1}) + pyraclostrobin (67 g kg^{-1}))	Small scale	Spray*	1.35 kg/ha
	Programme	Spray**	1.35 kg/ha
Subdue (metalaxyl-M (480 g L^{-1}))	Small scale	Drench	12.5 ml/100L @ 10% of pot vol
Fubol Gold (mancozeb (640 g kg^{-1}) + metalaxyl-M (40 g kg^{-1}))	Programme	Spray	1.9 kg/ha
Proplant (propamocarb hydrochloride (722 g L^{-1}))	Small scale	Drench	15 ml product /m^2 @ 3 L/m^2
	Programme	Drench	15 ml product /m^2 @ 3 L/m^2
HDC F33 (experimental)	Small scale	Spray*	2.5 L/ha
	Programme	Spray**	2.5 L/ha
HDC F34 (experimental) - Now marketed as **Percos**	Small scale	Spray*	0.8 L/ha
	Programme	Spray**	0.8 L/ha
HDC F64 (experimental)	Small scale	Soil incorporation	2.4 kg/m^3 potting soil
	Programme	Soil incorporation	2.4 kg/m^3 potting soil
HDC F114 (experimental)	Small scale	Spray*	1.6 kg/ha
HDC F147 (experimental)	Programme	Spray**	0.05 kg/ha

* Sprays application volume 1000 L water/ha; ** see Table 2 for spray application volume

Table 2. Protectant fungicide programmes trialed for the control of impatiens downy mildew caused by a metalaxyl-M isolate of *Plasmopara obducens*.

Prog No.	Treatment (a.i.)	Number of applications in programme	T1* 3 days after potting (3rd May 2012)	T2* (10th May 2012)	T3* (17th May 2012)	T4* (24th May 2012)
1	Water control	4	✓	✓	✓	✓
Standard programme						
2	Std prog	3	Proplant drench (propamocarb HCL)	Fubol Gold (mancozeb + metalaxyl-M)	Previcur Energy (fosetyl aluminium + propamocarb HCL)	-
Single product programmes						
3A	Fenomenal (fenamidone + fosetyl aluminium)	2	✓	-	✓	-
3B		4	✓	✓	✓	✓
4A	Paraat (dimethomorph)	2	✓	-	✓	-
4B		4	✓	✓	✓	✓
5A	Revus (mandipropimid)	2	✓	-	✓	-
5B		4	✓	✓	✓	✓
6A	Signum (pyraclostrobin + boscalid)	2	✓	-	✓	-
6B		4	✓	✓	✓	✓
7A	HDC F33 (confidential)	2	✓	-	✓	-
7B		4	✓	✓	✓	✓
8A	HDC F34 (Now marketed as Percos)	2	✓	-	✓	-
8B		4	✓	✓	✓	✓
9A	HDC F147 (confidential)	2	✓	-	✓	-
9B		4	✓	✓	✓	✓
10 (9)	HDC F64 (confidential)	1	Soil incorporation before potting	-	-	-
Experimental programmes						
11	Exp. prog 1	2	Paraat	-	Fenomenal	-
12	Exp. prog 2	3	Fenomenal	Paraat	-	Revus
13	Exp. prog 3	4	Revus	HDC F33	HDC F34 (Now marketed as Percos)	Paraat

* applications applied in 1000L water at T1 and T2, 2000Lwater at T3 and 3000L water at T4

✓ indicates spray, - indicates no spray

The trial was inoculated on 15/05/13 with a *P. obducens* sporangia suspension at a concentration of $1.7x10^4$ sporangia/ml. At this stage of the trial the four-spray programmes had received two applications and the two-spray programmes had received one application. The inoculation timing was used to challenge the longevity of a product, allowing a comparison to be made for inoculum arriving 12 days after application (two-spray programme) and five days after application (four-spray programmes).

Plants were assessed for disease symptoms two, four and six weeks after inoculation (29/5/13, 13/06/13 and 26/06/13 respectively), with the first assessment planned to coincide

with the time when commercially grown plants would be dispatched. At each assessment disease incidence (percentage of plants infected per treatment) and disease severity (percentage of leaf area sporulating per plant) were recorded. The second and third assessments established the longevity of any control under high inoculum pressure.

Crop safety trial

Twelve fungicides (Table 3) were examined in a crop safety trial against seedlings from the Impatiens DeZire and Accent series. Three colours (white, lavender/lilac and red) of each series were sown on the 30/04/13 and fungicides applied approximately three weeks later (24/05/13) at full (1N) and half rates (0.5N). All treatments were applied as sprays in a water volume of 1000 L/ha, with the exception of Proplant which was applied as a drench at 30,000 L/ha (3 L/m^2).

Table 3. Treatment and application rates used in impatiens seedling crop safety trial

	Water		Application rate			
Treatment	**Rate**		**1N**		**0.5N**	
Untreated	1,000	L/ha	-	-	-	-
Proplant	30,000	L/ha	150	L/ha	75	L/ha
Fenomenal	1,000	L/ha	4.5	kg/ha	2.25	kg/ha
Paraat	1,000	L/ha	3	kg/ha	1.5	kg/ha
Revus	1,000	L/ha	0.6	L/ha	0.3	L/ha
Signum	1,000	L/ha	1.35	kg/ha	0.675	kg/ha
HDC F33	1,000	L/ha	2.5	L/ha	1.25	L/ha
HDC F34 (Now marketed as **Percos**)	1,000	L/ha	0.8	L/ha	0.4	L/ha
HDC F147	1,000	L/ha	0.05	kg/ha	0.025	kg/ha
Fubol Gold	1,000	L/ha	1.9	kg/ha	0.95	kg/ha
Karamate	1,000	L/ha	2	kg/ha	1	kg/ha
Previcur Energy	1,000	L/ha	2.5	L/ha	1.25	L/ha

Assessments of phytotoxicity and the number of deformed seedlings for each series and colour were made one week after treatment (31/05/13). Assessment of the number of flowering plants and the number with and without buds was undertaken at a second assessment carried out once plants were flowering (25/06/13).

Results and Discussion

Single product efficacy testing - small scale

All spray treatments gave significant disease reduction compared to the controls (Figure 1), with Fenomenal (fenamidone and fosetyl aluminium), Revus (mandipropamid), Paraat (dimethomorph), HDC F114 and HDC F33 all reducing disease by over 97%. There were

few significant differences between the spray treatments, with the exception that the control achieved by HortiPhyte was significantly lower than all other spray applications. Even though the disease reduction achieved by HDC F34 (now marketed as Percos) and Previcur Energy was not significantly different to the majority of the spray treatments applied, it was less than 90% (85 and 74% respectively) and could potentially be considered as insufficiently effective for use in a fungicide programme. Overall, the levels of control achieved by the spray applications were similar to those observed for the metalaxyl-M sensitive isolate tested as part of HDC project PC 230a, however, in the current test only treatments with Paraat and HDC F114 gave 100% disease control.

The level of control achieved through the use of a soil drench/soil incorporation treatment was lower than for the spray treatments, with only HDC F64 providing a significant level of downy mildew control compared to the control, however this still only provided 30% disease control in these tests (Figure 1). Trial data and statistical analysis are shown in Appendix II Table i.

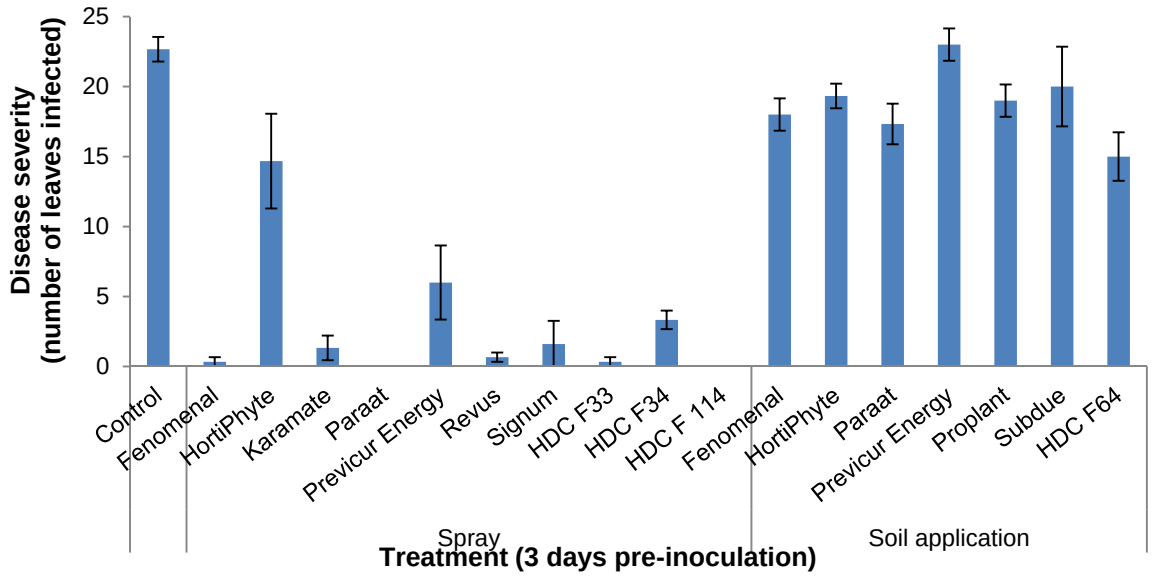

Figure 1. The effect of fungicide treatment on control of impatiens downy mildew infections caused by a metalaxyl-M resistant strain of *Plasmopara obducens* collected during 2011. F34 is now marketed as Percos.

These data indicate that products are available which could potentially provide good protectant activity against both the metalaxyl-M sensitive and resistant isolate. Fungicide programmes based on a number of these products were identified (Table 2) and taken

forward for testing on a semi-commercial-scale. Even though HDC F114 gave good control in the initial tests it was not taken forward as following further discussions with the manufacturers, it seemed less likely that approval for use on protected ornamental crops would be sought in the near future.

Fungicide programme efficacy testing (semi-commercial scale)

The initial laboratory scale tests were followed up with a semi-commercial scale trial which tested the efficacy of 12 fungicide programmes for control of a metalaxyl-M resistant isolate of *P. obducens*. The tests were carried out using impatiens 'DeZire White' grown in 6-packs.

The first signs of disease were observed in the trial on control plots (25/05/13) 10 days after inoculation. Plants were first assessed for disease on 29/05/13, which was five days after the final treatment and five weeks after potting; this later stage relating to the point when plants would be dispatched in a commercial situation. By this stage there was 100% disease incidence on the control plots (Figure 2) with a mean severity of 66% of the leaf area sporulating per plant (Figure 3). All fungicide programmes, except the single product programmes using HDC F147, significantly reduced the incidence of downy mildew caused by the metalaxyl-M resistant isolate. No disease (based on signs of sporulation) was present for 9 of the fungicide programmes, the 2-spray and 4-spray Fenomenal, Paraat and HDC F33 single product programmes, the 4-spray Revus single product programme and the 3-spray and 4-spray experimental programmes. However, only four programmes, the 4-spray Paraat, Revus and HDC F33 single product programmes, and the 3-spray experimental programme, were clear of disease when assessed for disease incidence. The incidence assessment included leaves which showed signs of disease e.g. yellowing, but had not yet sporulated, in addition to sporulating leaves which explains the lower number of programmes clear of disease. Only a very low disease incidence (1%) was recorded for the 4-spray experimental programme. At this stage there was also a low incidence of disease (2%) in the standard fungicide programme.

All 4-spray single product programmes had lower disease levels than the equivalent 2-spray programme with significant reductions following the Revus, Signum (pyraclostrobin and boscalid) and HDC F34 (* now marketed as Percos) treatments. The difference between the 2 and 4-spray programmes can be explained from the fungicide timing trial carried out as part of the HDC project PC230a.

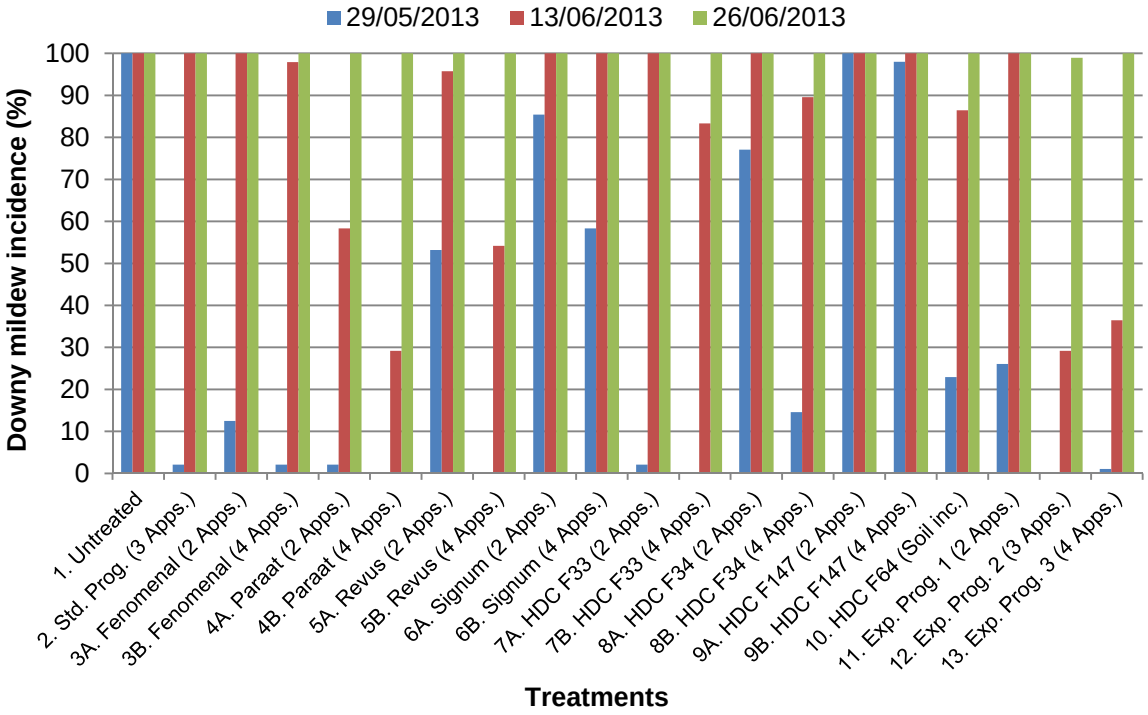

Figure 2. Efficacy of fungicide programmes (on three assessment dates) on the incidence of impatiens downy mildew caused by a metalaxyl-M resistant isolate of *Plasmopara obducens*. F34 is now marketed as Percos.

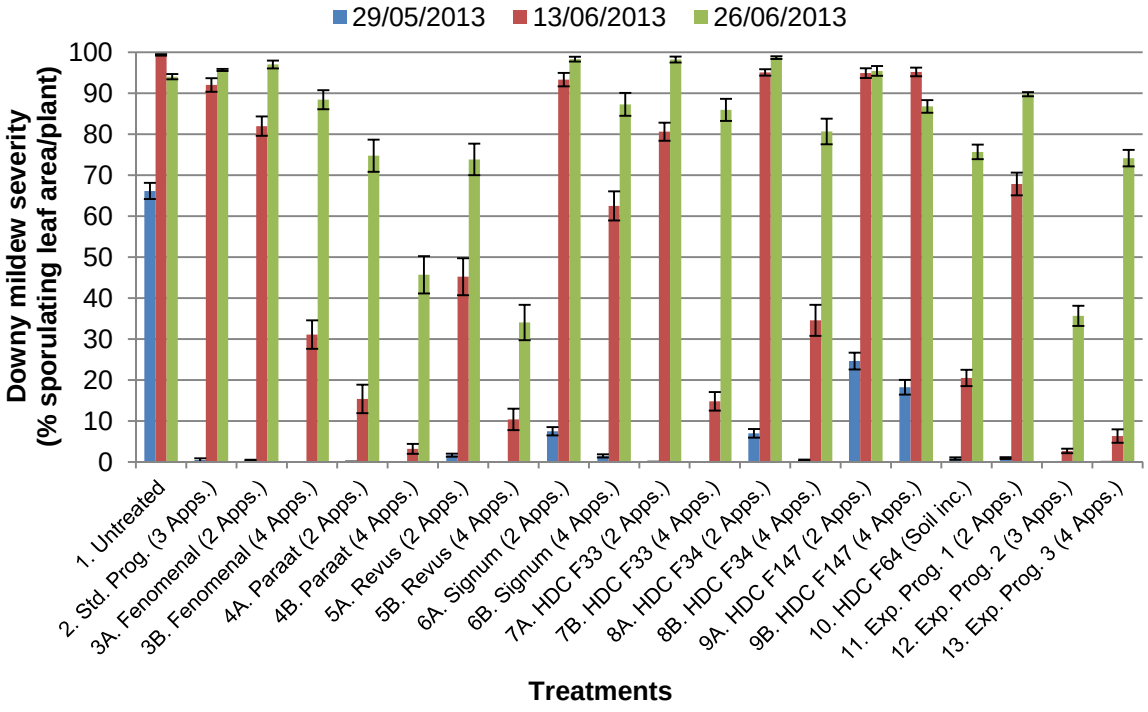

Figure 3. Efficacy of fungicide programmes (on three assessment dates) on the severity of impatiens downy mildew caused by a metalaxyl-M resistant isolate of *Plasmopara obducens*. F34 is now marketed as Percos.

This work showed that the efficacy of a product with good activity against, in this case, a metalaxyl-M sensitive isolate of *P. obducens* lasted for about 7 days before activity declined when applied as a protectant. Products applied as a curative were shown to be less able to control the disease than a protectant application but still gave reasonable control if applied two days after inoculation. In the current trial, treatments in the 2-spray single product programmes were applied 12 days before and 2 days after inoculation. As indicated earlier the first treatment is likely to have had little effect on disease development, however the second treatment would have had some curative effect. The relative disease incidence recorded for the different products used in the 2-spray programmes (Figure 2) also correlated well with the curative results obtained in PC230a, with HDC F33 and Paraat providing the best curative control in PC230a (80 and 70% respectively) and also giving the best 2-spray programme control in this trial. On the other hand, treatments closest to inoculation in the 4-spray single product programmes were applied 5 days before and 2 days after inoculation, both these timings would provide good control of the disease and hence little or no disease was recorded for most products. This gap between inoculation and closest fungicide treatment also helps explain the differences between the three experimental programmes examined.

The second and third assessments provided evidence of how long programme efficacy lasted under continuous high inoculum pressure; the inoculum pressure experienced by the programmes in this trial would be far higher than those likely to be experienced in a commercial situation (at least in the early stages of infection & disease development). The time between infection and sporulation is generally between 8 and 14 days depending on the ambient temperature. In this trial plants were inoculated 15/05/13 and disease first recorded 10 days later on the 25/05/13. If we assume that this was a second inoculation/infection point which then led to a second round of symptoms developing 10 days later which then led to a third inoculation/infection point and so on, then by the second assessment there would have been two cycles of symptom development and by the third assessment four cycles.

Programmes which performed best at the second disease assessment were the 4-spray Paraat and Revus single product programmes, and the 3- and 4-spray experimental programmes (both of which included Paraat and Revus). This was particularly obvious when looking at disease severity (Figure 3). With the exception of HDC F147, which was not significantly different from the untreated, the four-spray applications continued to perform significantly better than the two-spray programmes. The difference in visual signs of disease for a number of the programmes at the second assessment is shown in Figure 4.

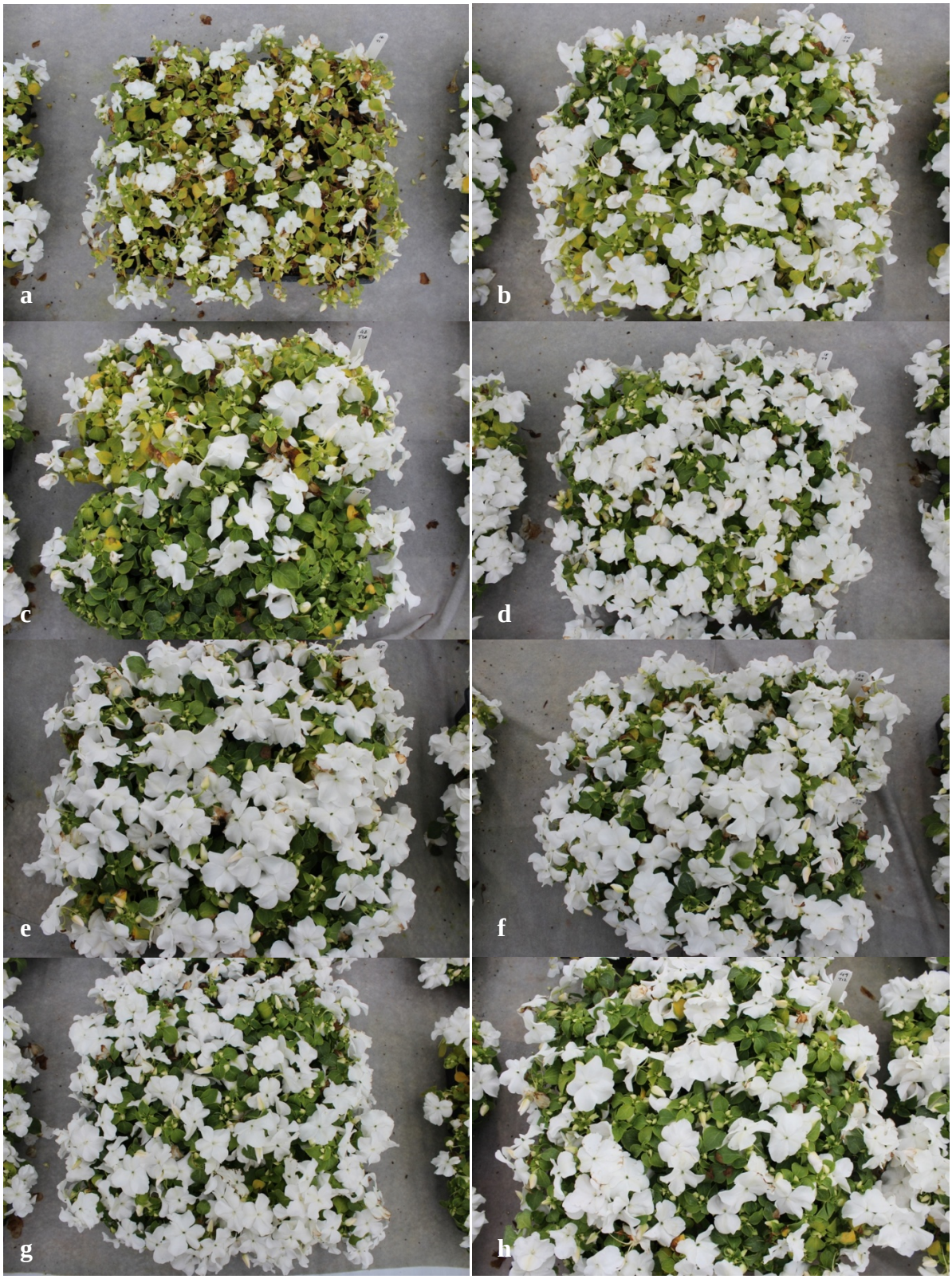

Figure 4. Plot photos taken at the second assessment on 13th June: a) Untreated, b) Standard programme, c) HDC F33 split plot (2-spray upper, 4-spray lower), d) Soil incorporation, e) Paraat split plot (2-spray upper, 4-spray lower), f) Revus split plot (2-spray upper, 4-spray lower), g) Experimental 3-spray programme, h) Experimental 4-spray programme.

By the third assessment there was 100% disease incidence in all treatments (Figure 2), however differences in disease severity (Figure 3) were observed for three programmes: the 4-spray single product programmes using Revus or Paraat and the 3-spray experimental programme, all of which had less than 50% leaf area sporulating. All other treatments had more than 74% leaf area sporulating per plant.

It is important to note there that at point of sale Impatiens plants with even a low disease incidence may present a problem commercially as retailers and end-user customers are unlikely to apply further fungicide applications post-sale. Under adverse i.e. wet weather conditions the disease, if present, is likely to develop to epidemic proportions, particularly in display beds in soil-grown parkland settings where the likelihood of leaf surface moisture for infection is higher than say in hanging baskets or pots & containers raised off the ground & with improved air circulation to dry the foliage out.

Trial data and statistical analysis are shown in Appendix II (Table ii).

Crop safety trial

Twelve fungicides were examined in crop safety trials against seedlings from the impatiens series DeZire and Accent, both mixed colour (white, red, lavender (DeZire) and lilac (Accent)). Seedlings were tested against full and half rate applications of each treatment, with assessments of phytotoxicity and the number of deformed seedlings for each series and colour made one week after treatment and again once the plants were flowering. Following the first assessment some plant deformities were recorded, however these seemed to relate to the impatiens series or colour rather than the chemical treatment with no significant difference between treatment and control plants. No other signs of phytotoxicity were observed. Following the second assessment differences between treatment and control plants were only noticed for the impatiens from the Accent series following treatment with Fubol Gold (metalaxyl-M/mancozeb) where there appeared to be a higher number of deformed blind plants. Data and statistical analyses are shown in Appendix II (Tables iii-vi).

Figure 5. View of crop safety trial flowering in the trial glasshouse at STC.

Conclusions

- The small scale single product efficacy trial identified a number of products which had potential for controlling the metalaxyl-M resistant *P. obducens*. These included products already approved for use on protected ornamentals such as Revus, Paraat and Fenomenal and an experimental coded product HDC F33.
- In the semi-commercial scale programme trial a number of programmes were identified which had potential to control the metalaxyl-M resistant *P. obducens*. In general these included Revus and Paraat, however programmes including Fenomenal and HDC F33 also performed well.
- There was no evidence of phytotoxicity, over and above those observed on the controls, for any of the products tested on seedling of *I. walleriana*.

Future work

- Monitoring the sensitivity to metalaxyl-M of *P. obducens* isolates involved in any future outbreaks (from both nurseries and parks/gardens) would provide an early warning of products likely to provide disease control. Additionally it would help determine the prevalence, persistence and geographical distribution of the metalaxyl-M resistant strain in the wider environment.

- Determine whether wild plant species are potential sources of *P. obducens* inoculum, e.g. *Impatiens noli-tangere* (a native impatiens species to the UK) or Himalayan (Indian) balsam (*I. glandulifera*), which then act as an annual and persistent infection source to commercially grown impatiens.
- Determine the susceptibility of other cultivated impatiens to the disease e.g. *I. hawkeri* (New Guinea types) and establish whether these are potential sources of resistance that can be transferred to *I. walleriana* in the longer-term.

Knowledge and Technology Transfer

- HDC News Article – December 2013
- HDC News Article – February 2013
- BPOA Technical Seminar – February 2013
- Gardeners Question Time – May 2013
- HDC News Article planned for February 2014

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APPENDICES

Appendix I

Programme trial diary

1.	Seedlings sourced from commercial nursery	17th April 2013
2.	Plants treated with mancozeb	22nd April 2013
3.	Seedlings potted into 6 packs	30th April 2013
4.	1st programme treatment applied	3rd May 2013
5.	2nd programme treatment applied	10th May 2013
6.	Trial inoculated	15th May 2013
7.	3rd programme treatment applied	17th May 2013
8.	Maintenance treatments of Conserve (spinosad) applied to control thrips	22nd May 2013
9.	4th programme treatment applied	24th May 2013
10.	Maintenance treatments of Conserve (spinosad) applied to control thrips	28th May 2013
11.	Disease assessment	29th May 2013
12.	Disease assessment	13th June 2013
13.	Disease assessment	26th June 2013

Trial Plan for Commercial Scale Fungicide Programme Testing- Spring 2013

Rep 1		Rep 2		Rep 3		Rep 4	
Plot	**Trt**	**Plot**	**Trt**	**Plot**	**Trt**	**Plot**	**Trt**
13	4A (Paraat – 2 spray) 4B (Paraat – 4 spray)	14	6A 6B	39	10	40	8A 8B
12	11 (Exp prog 1) (2 spray)	15	9A 9B	38	2	41	10
11	8A (HDC *F34 – 2 spray) 8B (HDC *F34 – 4 spray) (*now marketed as Percos)	16	1	37	11	42	7A 7B
10	2 (Std prog) (3 spray)	17	8A 8B	36	12	43	3A 3B
9	12 (Exp prog 2) (3 spray)	18	10	35	9A 9B	44	6A 6B
8	7A (HDC F33 – 2 spray) 7B (HDC F33 – 4 spray)	19	3A 3B	34	5A 5B	45	4A 4B
7	5A (Revus – 2 spray) 5B (Revus – 4 spray)	20	7A 7B	33	6A 6B	46	9A 9B
6	10 (HDC F64)	21	5A 5B	32	13	47	11
5	13 (Exp prog 3) (4 spray)	22	4A 4B	31	7A 7B	48	12
4	6A (Signum – 2 spray) 6B (Signum – 4 spray)	23	12	30	1	49	13
3	1 (Control)	24	2	29	3A 3B	50	5A 5B
2	9A (HDC F147 – 2 spray) 9B (HDC F147 – 4 spray)	25	11	28	8A 8B	51	2
1	3A (Fenomenal – 2 spray) 3B (Fenomenal – 4 spray)	26	13	27	4A 4B	52	1

Appendix II – Trials data

Statistical analysis for the small-scale efficacy tests.

Table i

Application method	Treatment	Number of diseased leaves		% Control
	Control	22.67	e	
Spray	Fenomenal	0.33	a	98.5
	Hortiphyte	14.67	c	35.3
	Karamate	1.33	a	94.1
	Paraat	0	a	100
	Previcur Energy	6	b	73.5
	Revus	0.67	a	97.1
	Signum	1.6	ab	92.6
	HDC F33	0.33	a	98.5
	HDC F34 (now marketed as Percos)	3.33	ab	85.3
	HDC F114	0	a	100
Soil application	Fenomenal	18	cd	20.6
	Hortiphyte	19.33	de	14.7
	Paraat	17.33	cd	23.5
	Previcur Energy	23	de	0
	Proplant	19	cde	16.2
	Subdue	20	e	8.8
	HDC F64	15	cd	33.8
LSD (P=.05)		4.46		
Standard Deviation		5.96		
Grand Mean		10.19		
Prob(F)		<0.001		

Semi- commercial scale programme trial

Table ii. Disease incidence (percentage of plants sporulating per treatment) and severity (percentage of leaf area sporulating per plant) at each assessment date

Assesment date	29/05/2013				13/06/2013				26/06/2013			
Treatment	**Incidence**		**Severity**		**Incidence**		**Severity**		**Incidence**		**Severity**	
1. Untreated	100%	a	66%	a	100%	a	99%	a	100%	a	94%	ab
2. Std. Prog. (3 Apps.)	2%	fg	0%	de	100%	a	92%	cde	100%	a	96%	a
3A. Fenomenal (2 Apps.)	13%	ef	0%	de	100%	a	82%	def	100%	a	97%	ab
3B. Fenomenal (4 Apps.)	2%	fg	0%	e	98%	ab	31%	jkl	100%	a	88%	abc
4A. Paraat (2 Apps.)	2%	fg	0%	de	58%	f	15%	lmn	100%	a	75%	cde
4B. Paraat (4 Apps.)	0%	g	0%	e	29%	g	3%	op	100%	a	46%	f
5A. Revus (2 Apps.)	53%	d	2%	cde	96%	abc	45%	ij	100%	a	74%	de
5B. Revus (4 Apps.)	0%	g	0%	e	54%	f	10%	mno	100%	a	34%	fg
6A. Signum (2 Apps.)	85%	b	8%	c	100%	a	93%	bcd	100%	a	98%	a
6B. Signum (4 Apps.)	58%	cd	1%	cde	100%	a	63%	ghi	100%	a	87%	a-d
7A. HDC F33 (2 Apps.)	2%	fg	0%	de	100%	a	81%	efg	100%	a	98%	a
7B. HDC F33 (4 Apps.)	0%	g	0%	e	83%	de	15%	lmn	100%	a	86%	a-d
8A. HDC *F34 (2 Apps.)	77%	c	7%	cd	100%	a	95%	abc	100%	a	99%	a
8B. HDC *F34 (4 Apps.)	15%	ef	0%	de	90%	bcd	35%	jk	100%	a	81%	bcd
9. HDC F64 (Soil inc.)	23%	e	1%	cde	86%	cd	21%	klm	100%	a	76%	cde
10. Exp. Prog. 1 (2 Apps.)	26%	e	1%	cde	100%	a	68%	fgh	100%	a	90%	ab
11. Exp. Prog. 2 (3 Apps.)	0%	g	0%	e	29%	g	3%	op	99%	b	36%	fg
12. Exp. Prog. 3 (4 Apps.)	1%	fg	0%	de	36%	g	6%	nop	100%	a	74%	cde
13A. HDC F147 (2 Apps.)	100%	a	25%	b	100%	a	95%	abc	100%	a	95%	ab
13B. HDC F147 (4 Apps.)	98%	a	18%	b	100%	a	95%	abc	100%	a	87%	abc
LSD (P=.05)	16.898	t	6.967		15.351	t	11.61	t	1.156		13.65	
Standard Deviation	11.949	t	4.927		10.854	t	8.21	t	0.817		9.652	
CV	41.65		64.56		15.02		17.69		0.82		11.84	
Grand Mean	28.69	t	7.63		72.28	t	46.42	t	99.92		81.51	
Prob(F)	0.0001		0.0001		0.0001		0.0001		0.4782		0.0001	

Means followed by same letter do not significantly differ (P=.05, LSD). * Now marketed as Percos
t=Mean descriptions are reported in transformed data units, and are not de-transformed.

Crop Safety Trial

Tables iii-vi. Show the percentage of deformed seedlings at the first assessment and percentage of plants not flowering at the second assessment for 0.5N and 1N application rates.

DeZire White		% deformed seedlings 31/05/2013				% plants not flowering 25/06/2013			
No.	**Treatment**	**0.5N**		**1N**		**0.5N**		**1N**	
1	untreated	14.02	a	14.92	ab	2.7	a	2.16	ab
2	Proplant	9.5	ab	5.03	b	1.83	a	0	b
3	Fenomenal	10.46	ab	6.85	b	3.2	a	1.45	ab
4	Paraat	10.05	ab	10.77	ab	2.74	a	3.82	a
5	Revus	10.66	ab	15.92	ab	3.2	a	3.56	a
6	Signum	7.49	ab	8.6	ab	4.21	a	1.45	ab
7	HDC F33	11.16	ab	22.57	a	1.83	a	1.45	ab
8	HDC *F34	12.91	ab	13.78	ab	0.86	a	0.86	ab
9	HDC F147	1.79	b	4.02	b	0.75	a	0.57	ab
10	Fubol Gold	6.46	ab	3.45	b	0.75	a	0.63	ab
11	Karamate	5.18	ab	12.18	ab	0.75	a	0.57	ab
12	Previcur Energy	6.61	ab	12.88	ab	0.75	a	1.55	ab
LSD (P=.05)		2.165	t	2.072	t	1.604	t	0.63	t
Standard Deviation		1.499	t	1.435	t	1.111	t	0.436	t
CV		50.01		43.78		72.88		122.16	
Grand Mean		3	t	3.28	t	1.52	t	0.36	t
Prob(F)		0.715		0.2077		0.8936		0.6154	

Means followed by same letter do not significantly differ (P=.05, LSD). * Now marketed as Percos
t=Mean descriptions are reported in transformed data units, and are not de-transformed.

DeZire Lavender		% deformed seedlings 31/05/2013				% plants not flowering 25/06/2013			
No.	**Treatment**	**0.5N**		**1N**		**0.5N**		**1N**	
1	untreated	6.4	abc	14.55	ab	3.17	a	3.36	a
2	Proplant	14.57	a	3.08	b	1.27	a	0.82	ab
3	Fenomenal	16.21	a	16.71	a	0.32	a	1.45	ab
4	Paraat	0.32	c	16.13	a	0.65	a	0.57	ab
5	Revus	0.92	c	7.76	ab	0.58	a	1.45	ab
6	Signum	2.94	abc	8.11	ab	2.83	a	0	b
7	HDC F33	7.87	abc	10.82	ab	0.32	a	0.57	ab
8	HDC *F34	15.81	a	15.48	ab	2.51	a	0.57	ab
9	HDC F147	1.27	bc	8.62	ab	1.27	a	0.63	ab
10	Fubol Gold	7.44	abc	11.06	ab	0.32	a	1.55	ab
11	Karamate	12.37	ab	9.88	ab	1.27	a	2.83	ab
12	Previcur Energy	1.75	bc	4.14	ab	0.32	a	0	b
LSD (P=.05)		14.664	t	2.127	t	11.655	t	0.585	t
Standard Deviation		10.156	t	1.473	t	8.072	t	0.405	t
CV		71.84		45.36		137.69		140.49	
Grand Mean		14.14	t	3.25	t	5.86	t	0.29	t
Prob(F)		0.0439		0.4859		0.9307		0.4814	

Means followed by same letter do not significantly differ (P=.05, LSD). * Now marketed as Percos
t=Mean descriptions are reported in transformed data units, and are not de-transformed.

DeZire Red		% deformed seedlings 31/05/2013				% plants not flowering 25/06/2013			
No.	Treatment	0.5N		1N		0.5N		1N	
1	untreated	11.5	abc	14.25	a	2.16	ab	1.85	ab
2	Proplant	12.75	abc	14.75	a	1.78	ab	0	b
3	Fenomenal	17	a	14.75	a	1.45	ab	1.78	ab
4	Paraat	7	abc	14.75	a	2.08	ab	2.16	ab
5	Revus	6	abc	19.5	a	0	b	4.48	a
6	Signum	2.75	c	11.75	a	0.86	b	5.43	a
7	HDC F33	3.5	bc	20.25	a	2.16	ab	2.24	ab
8	HDC *F34	14	ab	13	a	2.66	ab	3.46	ab
9	HDC F147	6.5	abc	15.5	a	1.45	ab	1.45	ab
10	Fubol Gold	11.5	abc	21	a	1.45	ab	1.78	ab
11	Karamate	13	abc	15	a	1	b	1.45	ab
12	Previcur Energy	10.5	abc	10.5	a	6.93	a	0.57	ab
LSD (P=.05)		11.17		14.427		0.565	t	0.735	t
Standard Deviation		7.736		9.992		0.391	t	0.509	t
CV		80.03		64.81		91.41		110.64	
Grand Mean		9.67		15.42		0.43	t	0.46	t
Prob(F)		0.258		0.9322		0.3569		0.6886	

Means followed by same letter do not significantly differ (P=.05, LSD). * Now marketed as Percos
t=Mean descriptions are reported in transformed data units, and are not de-transformed.

Accent White		% deformed seedlings 31/05/2013				% plants not flowering 25/06/2013			
No.	Treatment	0.5N		1N		0.5N		1N	
1	untreated	20.73	a	14.1	a	9.24	a	9.02	a
2	Proplant	9.93	ab	6.1	ab	0.32	b	1.45	abc
3	Fenomenal	11.47	ab	9.86	ab	2.3	ab	0	c
4	Paraat	1.89	bc	5	ab	3.41	ab	2.85	abc
5	Revus	9.79	ab	6.7	ab	0.32	b	0.82	bc
6	Signum	0.32	c	1.2	b	1.27	b	0.57	bc
7	HDC F33	2.93	bc	9.86	ab	1.27	b	0.57	bc
8	HDC *F34	3.41	bc	5.29	ab	0.92	b	0.57	bc
9	HDC F147	5.55	bc	5.51	ab	0.32	b	0.86	bc
10	Fubol Gold	11.34	ab	10.95	ab	3.73	ab	5.87	ab
11	Karamate	9.06	ab	4.29	ab	4.29	ab	0.82	bc
12	Previcur Energy	2.73	bc	4.86	ab	0.32	b	0	c
LSD (P=.05)		12.856	t	14.42	t	11.221	t	0.649	t
Standard Deviation		8.904	t	9.987	t	7.771	t	0.45	t
CV		60.9		67.31		101.92		128.87	
Grand Mean		14.62	t	14.84	t	7.62	t	0.35	t
Prob(F)		0.0381		0.7349		0.2333		0.0756	

Means followed by same letter do not significantly differ (P=.05, LSD). * Now marketed as Percos.
t=Mean descriptions are reported in transformed data units, and are not de-transformed.

Accent Lilac		% deformed seedlings 31/05/2013				% plants not flowering 25/06/2013			
No.	**Treatment**	**0.5N**		**1N**		**0.5N**		**1N**	
1	untreated	25.47	a	27.5	ab	4.8	bc	5.22	abc
2	Proplant	12.36	ab	15.25	bc	0.75	c	1.45	abc
3	Fenomenal	9.46	ab	32.5	a	7.99	ab	9.32	a
4	Paraat	10.56	ab	20.5	abc	6.09	abc	4.01	abc
5	Revus	24.42	a	22.75	abc	14.2	a	4.07	abc
6	Signum	5.88	b	11.25	c	6.79	ab	0.57	c
7	HDC F33	21.39	a	25.25	abc	10.93	ab	7.57	ab
8	HDC *F34	20.32	a	14.5	bc	3.98	bc	0.97	bc
9	HDC F147	18.49	ab	18.25	abc	8.36	ab	1.45	abc
10	Fubol Gold	19.76	a	27.5	ab	7.29	ab	3.46	abc
11	Karamate	11.26	ab	22	abc	3.99	bc	3.69	abc
12	Previcur Energy	19.34	ab	21	abc	6.51	ab	2.71	abc
LSD (P=.05)		1.96	t	15.044		1.507	t	0.704	t
Standard Deviation		1.357	t	10.419		1.044	t	0.488	t
CV		33.47		48.41		39.81		80.18	
Grand Mean		4.06	t	21.52		2.62	t	0.61	t
Prob(F)		0.1974		0.2253		0.1107		0.4192	

Means followed by same letter do not significantly differ (P=.05, LSD). * Now marketed as Percos.
t=Mean descriptions are reported in transformed data units, and are not de-transformed.

Accent Red		% deformed seedlings 31/05/2013				% plants not flowering 25/06/2013			
No.	**Treatment**	**0.5N**		**1N**		**0.5N**		**1N**	
1	untreated	46	ab	49.5	a	37	a	31.02	abc
2	Proplant	37	ab	33.75	a	19.75	bc	12.06	c
3	Fenomenal	27	b	43.25	a	22	abc	24.07	abc
4	Paraat	37.25	ab	31.75	a	19	bc	21.58	abc
5	Revus	37.25	ab	47.75	a	23.75	abc	24.78	abc
6	Signum	31	ab	43.5	a	25.5	abc	16.73	abc
7	HDC F33	46.75	a	42.75	a	29.75	ab	28.39	abc
8	HDC *F34	33.75	ab	48	a	9	c	27.07	abc
9	HDC F147	31.75	ab	46.25	a	29.25	ab	14.03	bc
10	Fubol Gold	38.75	ab	51.25	a	29.25	ab	38.71	a
11	Karamate	33.5	ab	49.5	a	19	bc	34.11	ab
12	Previcur Energy	43	ab	38.5	a	18.75	bc	18.7	abc
LSD (P=.05)		19.658		25.442		17.016		2.266	t
Standard Deviation		13.614		17.62		11.785		1.569	t
CV		36.88		40.22		50.15		31.94	
Grand Mean		36.92		43.81		23.5		4.91	t
Prob(F)		0.6502		0.8826		0.1706		0.3772	

Means followed by same letter do not significantly differ (P=.05, LSD). * Now marketed as Percos.
t=Mean descriptions are reported in transformed data units, and are not de-transformed.