Project title:	Control of downy mildew on shrub and herbaceous plants
Project number:	HNS 186
Project leader:	Dr Tim O'Neill, ADAS
Report:	Annual report, March 2013
Previous report	None
Key staff:	Kerry Maulden, Sean Allison, David Talbot and John Atwood, ADAS
Location of project:	Commercial nurseries, Norfolk and Worcs
Industry representatives:	Mr Alistair Hazell, Darby Nursery Stock Ltd, Methwold, Norfolk Mr Paul Howling, Howard Nurseries Ltd, Wortham, Norfolk Mr Chris Bowman, John Woods Nurseries Ltd, Woodbridge, Suffolk
Date project commenced:	1 April 2012
Date project completion due:	31 March 2014

DISCLAIMER

AHDB, operating through its HDC division seeks to ensure that the information contained within this document is accurate at the time of printing. No warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

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.

Dr Tim O'Neill

Principal Research Scientist

ADAS

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

Report authorised by:

Dr Barry Mulholland

Head of Horticulture

ADAS

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

CONTENTS

GROWER SUMMARY

Headline

- Thirteen treatments, including novel fungicides and biofungicides, a fungicide incorporated in the growing medium and a foliar fertiliser reduced downy mildew on *Geum*.
- Repeat applications of Fubol Gold damaged a small-leafed variety of *Hebe* but not a large-leafed variety.

Background and expected deliverables

Downy mildew diseases can seriously damage over a dozen nursery stock and herbaceous perennials including *Buddleia*, *Digitalis*, *Gaillardia*, *Lamium*, *Hebe*, Rose and *Veronica*. Fungicides are the primary method of control for most growers. The availability of fungicides for use on ornamentals is currently declining due to changing legislation. Furthermore, there is a risk of some fungicides failing to control downy mildew diseases due to selection of fungicide-resistant strains; this has recently occurred with metalaxyl-M (e.g. Fubol Gold WG) failing to control impatiens downy mildew. The SCEPTRE HortLink project is evaluating a wide range of new fungicides and biofungicides for downy mildew control on edible crops, initially on *Brassica*. The project will examine the most promising new products identified in the SCEPTRE HortLink project and elsewhere for control of downy mildews on two ornamental crops, and for their crop-safety to a range of woody and herbaceous ornamentals. Simple crop protection programmes, based where possible on products designed to reduce the risk of resistance build-up, will be devised and tested. The HDC Factsheet on downy mildew diseases will be updated.

The overall aim of the project is to improve control of downy mildew diseases. Specific project objectives in Year 1 were:

1. To determine the effectiveness of selected novel fungicides and biofungicides;
2. To devise and determine the effectiveness of some simple alternating programmes.

Summary of the project and main conclusions

Three fully replicated experiments were carried out in autumn 2012 on commercial nurseries. Objective 1 was examined in all experiments; Objective 2, which will be further investigated in Year 2, was examined in experiment 3.

Experiment 1 – Fungicides and biofungicides for control of Hebe downy mildew

Nine conventional fungicides, two biofungicides and a foliar fertiliser were evaluated as high volume sprays and Plant Trust (fosetyl-Al) as a growing medium incorporation, for control of downy mildew (*Peronospora grisea*) on *Hebe x franciscana* 'Variegata' in a low multispan tunnel on a nursery in Norfolk. The conventional fungicides comprised Fubol Gold (mancozeb + metalaxyl M), Signum (boscalid + pyraclostrobin), Fenomenal (fosetyl-Al + fenamidone), Infinito (flupicolide + propamocarb), Pergado Uni (mandipropamid), Previcur Energy (fosetyl-Al + propamocarb), Paraat (dimethomorph), Percos (ametoctradin + dimethomorph) and one coded products (F62); the biofungicides were both coded products (F60 and F61); the foliar fertiliser was Hortiphyte (potassium phosphite). Fungicides and the foliar fertiliser were applied every 14 days and the biofungicides every 7 days from 6 September to 20 December. The Plant Trust was incorporated and plants potted three weeks after other treatments were established. No downy mildew occurred despite the introduction of hebe plants affected by the disease into the tunnel. No crop damage or effect on plant quality was observed.

Experiment 2 – Fungicides and biofungicides for control of Geum downy mildew

The same treatments as used in Experiment 1 were examined for control of downy mildew (*Peronospora potentillae*) on *Geum* 'Mrs Bradshaw' on a nursery in Norfolk.

Plug plants were already infected by a low level of downy mildew at potting. The first two applications of all treatments were therefore applied at a 7 day interval (6 and 13 September) as is likely to be done in good commercial practice when downy mildew occurs, and thereafter at 14 (fungicide) or 7 (biofungicide) day intervals. All treatments reduced disease incidence and severity (Figure 1). Signum and Fubol Gold gave the best control, with Fenomenal, Percos, Previcur Energy, Hortiphyte and F62 almost as good. The two biofungicides (F60 and F61), Paraat and Plant Trust were slightly less effective than Fubol Gold and Signum in this experiment. Following cold weather in December and January, patches of leaf yellowing developed on 18-47% of plants that had been treated with Infinito, F61 and F62.

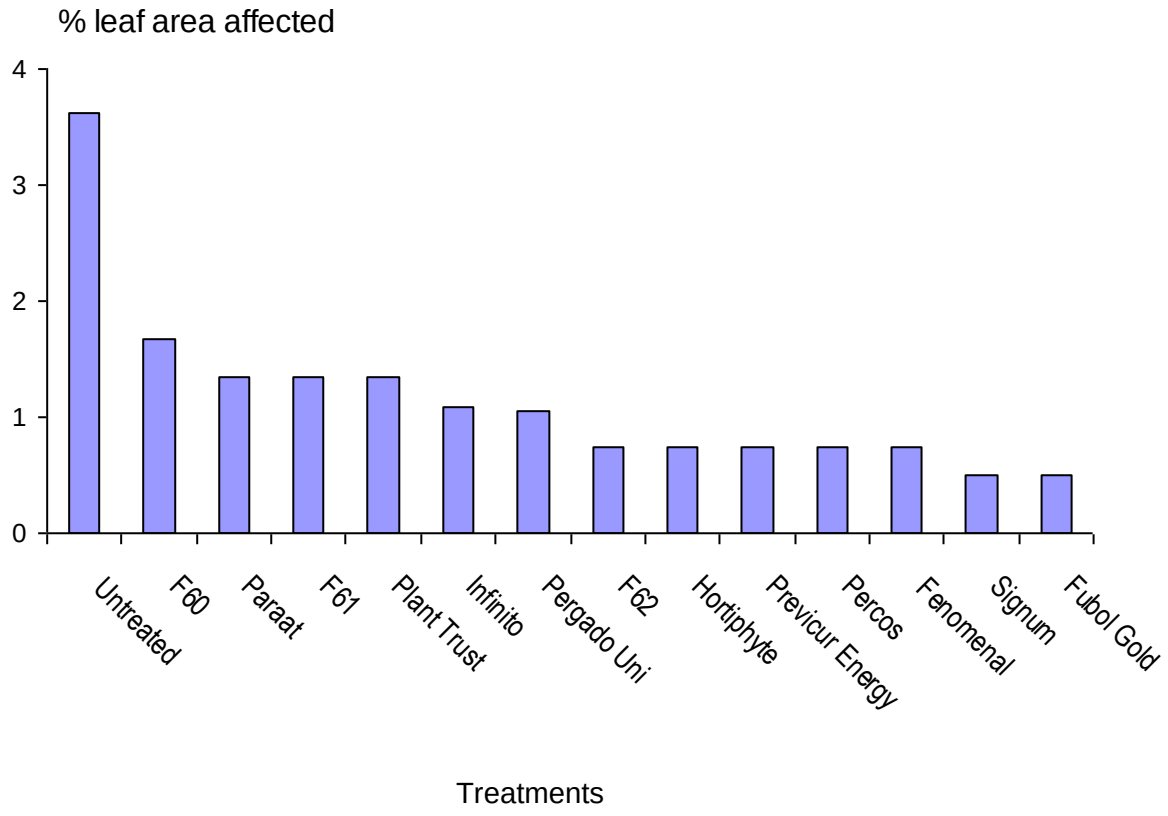

Figure 1. Effect of fungicides, biofungicides (F60 and F61) and a foliar fertiliser on *Geum* downy mildew, Norfolk – December 2012

Experiment 3 – Fungicide products and simple programmes for control of Hebe downy mildew

Seven treatments were evaluated for control of downy mildew on *Hebe* 'Frozen Flame' from 29 August to 19 December 2012. The treatments comprised Plant Trust incorporation in the growing medium; Fenomenal applied as a monthly drench and as a spray; programmes of Fenomenal, Signum and Hortiphyte each alternating with Fubol Gold every 14 days, and Hortiphyte as a monthly foliar spray. Downy mildew was first observed in mid September and increased in November. By 7 January 2013, downy mildew affected 14% leaf area on untreated plants. Disease severity appeared to be reduced by Plant Trust, by Fenomenal drenches and sprays, and by Hortiphyte sprays (Table 1). Fenomenal drench and spray treatments, applied at monthly intervals, were most effective and reduced the disease to around 1% leaf area affected. Treatment with Fubol Gold resulted in leaf tip pale discolouration, first visible 1 week after the third spray application (the maximum spray number); damage symptoms increased with a further spray (applied under an Experimental Permit) and some plants showed shoot tip dieback and plant collapse (Figure 2).

Table 1. Effect of fungicide programmes on *Hebe* downy mildew, Worcs – 2012

Product(s)	Application method	Total no. applications	% leaf area affected (7 Jan 2012)	% plants marketable
1. Untreated	-	0	14.3	75
2. Plant Trust	Incorporation	1	7.8	84
3. Fenomenal	Drench	5	1.6	97
4. Fenomenal	Spray	5	1.0	100
5. Fenomenal /Fubol Gold	Spray	9	-[a]	0
6. Signum /Fubol Gold	Spray	9	-	3
7. Hortiphyte /Fubol Gold	Spray	9	-	25
8. Hortiphyte	Spray	5	2.7	97

[a] Unable to assess downy mildew due to spray damage to plants; earlier observations indicate low disease levels.

In treatments 5-7, the two products were applied alternately every 2 weeks; treatments 3, 4 and 8 were applied monthly.

Figure 2. Close up of *Hebe* 'Frozen Flame' leaf damage after four sprays with Fubol Gold at 1.9 g/L

Table 2. Summary of products evaluated as sprays for control of downy mildew and their approval status (February 2013) for use on ornamental crops

Product	Active ingredient(s) (fungicide group)	Rate of use	Approval		Max spray number
			Outdoor (O)	Protected (P)	
1. Untreated	-	-	-	-	-
2. Fubol Gold	mancozeb (M3) + metalaxyl M (4)	1.9 kg/ha	✓ 0217/12	✓ 0217/12	3
3. Signum	boscalid (7) + pyraclostrobin (11)	1.35 kg/ha	✓ 1842/09	✓ 1842/09	2
4. Fenomenal	fosetyl-Al (33) + fenamidone (11)	2.5 kg/ha	NA	NA	-
5. Infinito	flupicolide (43) + propamocarb (28)	1.6 L/ha	✓0952/13	NA	4 if 1.6 L rate (O)
6. Percos	ametoctradin (45) + dimethomorph (40)	0.8 L/ha	✓ 0819/13	✓ 0819/13	4
7. Pergado Uni	mandipropamid (40)	0.6 L/ha	✓ 1605/12	✓ 1605/12	4 (O) 1 (P)
8. Previcur Energy	fosetyl-Al (33) + propamocarb (28)	2.5 L/ha	NA	NA	-
9. Hortiphyte	potassium phosphite	2.5 L/ha	✓	✓	NS
10. Paraat	dimethomorph (40)	0.36 kg/ha	-	✓ 2585/11	2
11. F62	Novel chemical	-	NA	NA	-
12. F60	Novel biological	-	NA	NA	-
13. F61	Novel biological	-	NA	NA	-
14. Plant Trust	fosetyl-aluminium (33)	Incorp	Label	Label	1

Spray applications were applied at 1000 L/ha. Fenomenal used as a drench was applied at 1.5 g/L, 200 ml/pot.

NA – Not approved for use as a spray treatment; treatment applied under an Experimental Permit. Note that Fenomenal is permitted for use on protected ornamentals as a drench with up to three applications per year at 50-150 g/100 L; Previcur Energy is permitted for use on protected ornamentals as a drench with up to two applications at a maximum of 30 L/ha.

LTAEU – Used under the Long Term Arrangements for Extension of Use.

NS – not stated.

Financial benefits

Downy mildew diseases can seriously damage some major shrub and herbaceous species. Losses in *Hebe* for example are estimated to exceed £200,000 annually. This project will benefit growers through identification of some new fungicides and biofungicides with activity against downy mildew and their potential for use on ornamentals. Development of sustainable programmes using fungicide and biofungicides that are crop-safe and effective will reduce losses and downgrading due to downy mildew.

Action points for growers

- Consider use of the following fungicides as high volume sprays for control of *Geum* downy mildew: Signum, Infinito (outdoor crops only), Fubol Gold, Paraat, Percos and Pergado Uni.
- Consider use of Plant Trust as a growing medium incorporation at potting and Fenomenal as a drench treatment after potting as components of programmes for control of downy mildew on *Geum* and *Hebe*.
- Use two or more fungicides from different mode of action group to reduce the risk of selecting resistant strains of downy mildew (see Table 2 for categorization of products by fungicide group).
- Test treat a small number of plants to check for phytotoxicity before using a fungicide widely on a new species or variety for the first time.
- Some novel fungicides and biofungicides with activity against downy mildew were identified in this project; HDC will issue publicity if and when these products are approved for use on ornamental crops.
- Note that Fenomenal and Previcur Energy are currently permitted on ornamentals only as drench treatments; applications to CRD for approvals to allow their use as spray treatments are being considered by HDC.
- Note that use of Percos outdoors is restricted to applications between June and September to container crops and that use on outdoor crops standing on hard surfaces is prohibited.
- Note that Hortiphyte applied as a foliar fertiliser can give incidental control of downy mildew on *Geum* and *Hebe*.

- Note that Fubol Gold may cause slight damage to some varieties of *Hebe* if the maximum number of permitted sprays (three) is used; and severe damage if this spray number is exceeded.
- Note that multiple applications of Infinito and cold (frosty) weather can result in leaf yellowing on *Geum*.

SCIENCE SECTION

Introduction

Downy mildews, although more sporadic than powdery mildews, are often the more damaging disease. They can spread rapidly through a crop often affecting new growth and make plants unmarketable through leaf blotches, yellowing and distortion, premature leaf fall and stunted growth. Factsheet 04/04 listed 14 susceptible nursery stock and herbaceous perennial species. From time to time new downy mildew problems arise through evolution, introduction from overseas or due to a change in cropping practices; Aquilegia downy mildew was recently found in the UK for the first time.

Fungicides are the cornerstone of downy mildew control for most growers. Due to the rapid and severe damage that can occur from downy mildew attack, it is usual to apply a programme of protective sprays to highly susceptible crops, rather than wait for the disease to occur before commencing treatment. Recent work on impatiens downy mildew (PC 230) for example, showed that fungicides applied from first symptoms gave virtually no control once it was present in a crop. Consequently it is necessary to have a range of fungicide products from different mode of action groups available for use in protectant programmes. However, the number of products available in the UK has recently declined and is likely to continue to decline, due especially to new EU pesticide regulation EC1107/2009.

Availability of products for control of downy mildew diseases on edible crops was identified as one of the crop protection gaps likely to arise in the near future as the new EU regulation EC1107/2009 takes effect. The Defra sponsored HortLINK SCEPTRE project (HL01109) supported by HDC (CP 77) in liaison with agrochemical and biopesticide suppliers, is screening a wide range of potential new pesticides and biopesticides on the most economically significant crop protection gaps of edible crops. A first screen of fungicides and biofungicides for control of brassica downy mildew has recently been completed; further work will be done on Brassica and lettuce downy mildew. The work proposed here aims to capitalise on the downy mildew results from SCEPTRE in order to identify as efficiently as possible the most effective new treatments for use on ornamentals.

Plant Trust, a new product containing fosetyl aluminium as a slow release granule for incorporation in growing media, has recently been launched for control of Phytophthora root rot in container-grown plants. It is known that foliar sprays and drenches of fosetyl aluminium (e.g. as Aliette 80WG) control downy mildew. It would be useful to determine if fosetyl aluminium incorporated into growing media controls downy mildew, and to what extent.

The overall aim of this work is to improve control of downy mildew diseases on shrubs and herbaceous ornamentals. The specific objective in Year 1 was: to identify and evaluate the efficacy of some novel fungicides and biofungicides with potential for control of downy mildew. Additionally, opportunity was taken to devise and determine the effectiveness of some simple alternating programmes, as a lead-in to further work on this Objective (Objective 2) in Year 2.

Materials and methods

Three fully replicated experiments were done on commercial nurseries in autumn 2012.

Site and crop details

Novel fungicides and biofungicides were evaluated for control of downy mildew on *Hebe* x franciscana 'Variegata' (Experiment 1) and *Geum* 'Mrs Bradshaw' (Experiment 2) on a nursery in Norfolk. The crops were grown on a sandbed with overhead irrigation in a multispan polytunnel with curtain sides. The *Hebe* were grown from nursery cuttings in 1 L pots; the *Geum* were grown from bought-in plug plants in 1.5 L pots. The nursery standard growing medium was used with reduced controlled release fertiliser (CRF) as appropriate in pots containing Plant Trust. Plants were potted in late August and the first sprays were applied on 6 September. A full crop diary is given in Appendix 1. The final sprays were applied on 20 December and a final assessment was done 18 days later on 7 January 2013.

Experiment 3 was done on a nursery in Worcestershire. Some simple alternating fungicide spray programmes, a comparison of Fenomenal applied as a high volume spray and as a drench, and Plant Trust as a growing medium incorporation, were evaluated for control of downy mildew on *Hebe* 'Frozen Flame'. The crop was grown on a sandbed with sub-irrigation in a glasshouse. Liners produced on the nursery were potted into 2 L pots on 20 August; fungicide spray and drench treatments commenced around 1 week later and continued until 20 December. A crop diary is given in Appendix 1.

Treatments

Treatments are detailed in Table 3 (Exps 1 and 2) and Table 4 (Exp 3). For Experiments 1 and 2, all sprays were applied every 14 days, except for the biofungicides (F60 and F61) which were applied weekly, at 1,000 L/ha using an Oxford Precision sprayer at 2-3 Bar pressure with medium spray quality (04F110 nozzles). In Experiment 2, the spray interval was reduced to 7 days for all treatments for the first two sprays after the disease was confirmed in the crop. For Experiment 3, sprays were applied at intervals as shown (Table

4) from 29 August (week 35) to 19 December (week 51) at 1,000 L/ha using a pressurised knapsack sprayer with medium nozzle; drenches were applied over the plant at 200 ml/pot.

Table 3. Summary of products evaluated for control of downy mildew in Experiments 1 and 2, Norfolk - 2012

Product	Active ingredient(s) (fungicide group)	Rate of use
1. Untreated	-	-
2. Fubol Gold	mancozeb (M3) + metalaxyl M (4)	1.9 kg/ha
3. Signum	boscalid (7) + pyraclostrobin (11)	1.35 kg/ha
4. Fenomenal	fosetyl-Al (33) + fenamidone (11)	2.5* kg/ha
5. Infinito	flupicolide (43) + propamocarb (28)	1.6 L/ha
6. Percos	ametoctradin (45) + dimethomorph (40)	0.8 L/ha
7. Pergado Uni	mandipropamid (40)	0.6 L/ha
8. Previcur Energy	fosetyl-Al (33) + propamocarb (28)	2.5 L/ha
9. Hortiphyte	potassium phosphite	2.5 L/ha
10. Paraat	dimethomorph (40)	0.36 kg/ha
11. F62	Novel chemical	
12. F60	Novel biological	
13. F61	Novel biological	
14. Plant Trust	fosetyl-aluminium (33)	2.4 kg/m^3

* Based on Belgium rate for lettuce downy mildew.

In Experiments 1 and 2, fungicides, biofungicides and the foliar fertiliser were applied from 6 September (week 36) to 20 December (week 51). The initial plan was to apply six sprays of fungicides at two week intervals and 12 sprays of biofungicides at weekly intervals; the trials were extended to nine sprays for fungicides and 16 sprays for biofungicides to allow increased time for downy mildew to develop. Due to late delivery, Plant Trust was not incorporated until 27 September (week 39), three weeks after the first application of other treatments.

Table 4. Treatment list for Experiment 3, Worcs - 2012

Product	Rate of use	Application method	Application timing (weeks after potting)								
			1	3	5	7	9	11	13	15	17
1. Untreated	-	-	-	-	-	-	-	-	-	-	-
2. Plant Trust	2.4 kg/m^3	Incorporation	✓	-	-	-	-	-	-	-	-
3. Fenomenal	1.5 g/L	Drench	✓	-	✓	-	✓	-	✓	-	✓
4. Fenomenal	2.5 g/L	Spray	✓	-	✓	-	✓	-	✓	-	✓
5. Fenomenal (F) Fubol Gold (FG)	2.5 g/L 1.9 g/L	Sprays	Fen	FG	Fen	FG	F	FG	F	FG	F
6. Signum (S) Fubol Gold (FG)	1.35 g/L 1.9 g/L	Sprays	S	FG	S	FG	S	FG	S	FG	S
7. Hortiphyte (H) Fubol Gold (FG)	2.5 g/L 1.9 g/L	Sprays	H	FG	H	FG	H	FG	H	FG	H
8. Hortiphyte	2.5 g/L	Spray	✓	-	✓	-	✓	-	✓	-	✓

In Experiment 3, treatments were applied from 29 August (week 35) to 19 December 2012 (week 51). The initial programme of six sprays was extended to nine sprays to allow increased time for downy mildew to develop.

Experiment design and data analysis

All experiments consisted of randomised block designs with four replicates. In Experiment 1 and 2 there was extra replication (eightfold) of the untreated. Plots consisted of 24 plants, arranged pot thick as 4 rows of 6; the central 8 plants were assessed. Results were examined by Generalised linear modeling or ANOVA as appropriate.

Assessments

In Experiments 1 and 2, untreated plants were examined at each weekly visit for symptoms of downy mildew (blotchy yellowing on upper leaf surface, grey sporulation on lower surface; distorted young leaves). At monthly intervals downy mildew was assessed as the number of plants affected per plot (of 8), and estimated % leaf area affected per plant.

On 1 November, plant vigour in Experiments 1 and 2 was recorded on a 1-9 scale:

1 – severely stunted growth, severe mildew (unsaleable)

3 – stunted growth, obvious mildew (unsaleable)

5 – average growth, slight mildew

7 – good growth, trace mildew

9 – excellent growth, no mildew

In Experiment 3, plants were inspected weekly by nursery staff for downy mildew and crop damage. A full assessment was done by ADAS staff on 7 January 2013. Downy mildew was assessed as in Experiments 1 and 2. Plant quality was assessed on 7 January 2013, on a 1-5 scale using the categories described below.

1 – severe damage and/or severe mildew (unsaleable)

2 – obvious damage and/or mildew (unsaleable)

3 – average growth; slight damage or mildew

4 – good growth; trace damage or mildew

5 – excellent growth; no damage or mildew

Results and discussion

Experiment 1 – Fungicides and biofungicides for control of Hebe downy mildew

No downy mildew occurred in the trial. This was despite the introduction of *Hebe* infector plants bearing downy mildew sporulation partway through the trial and the use of overhead irrigation to create leaf wetness conducive to infection. The variety used, *Hebe* x franciscana 'Variegata', is known to be susceptible to downy mildew. The reason for the lack of downy mildew is unknown. Possibly air movement in the multispan tunnel was sufficient to dry leaves of the small plants quite quickly after irrigation and leaf wetness periods were of insufficient duration. The temperature was more favourable to downy mildew during September and October (means of 11 ^{O}C and 15^{O}C) than the subsequent four months (4-7^{O}C) (Appendix 3). No leaf yellowing, leaf necrosis, stunted growth or other possible symptoms of phytotoxicity were observed on treated plants.

Experiment 2 – Fungicides and biofungicides for control of Geum downy mildew

Disease control

When the first spray was applied (6 September 2012) around 40% of plants were affected by downy mildew, with around 5% leaf area on these plants showing symptoms (mean of 2% leaf area affected across all plants). These plants were distributed evenly between the plots.

At the first assessment on 20 September, 1 week after application of two sprays to all treatments, there were significant differences between treatments in both disease incidence ($p = 0.013$; Table 5) and severity ($p < 0.001$; Table 6). The greater incidence of affected

plants was in the untreated control (59%), and this was reduced by Fubol Gold, Infinito, Pergado Uni, Previcur Energy, F60 and F61 (Table 5). The greatest disease severity at this time was in untreated plots (3.7% leaf area affected). Disease severity at this early stage was reduced by all treatments except Fenomenal, Hortiphye, F62 and Percos (Table 6).

The incidence of affected plants increased with time and by 14 December 2012 over 90% of untreated plants showed symptoms of downy mildew. All treatments except F60 reduced disease incidence (Table 5). At the assessment on 7 January downy mildew incidence had generally fallen slightly, due to shriveling and loss of badly affected leaves.

Disease severity on untreated plants changed little between 20 September and 14 December. There was some increase in downy mildew symptoms but there was also emergence and expansion of new leaves. On treated plants there was a general trend for disease severity to decrease with time (Table 6). On 14 December, after 8 sprays of fungicides and the foliar fertiliser, and 14 sprays of the biofungicides, disease severity was reduced by all treatments from 3.6% to 1.7% or less. Fubol Gold and Signum (0.5% leaf area affected) were the most effective products, closely followed by Fenomenal, Percos, Previcur Energy, Hortiphyte and F62 (0.8% leaf area affected). It should be noted that plug plants were kept bag for the Plant Trust treatment and potted three weeks later the other plants (due to late delivery of product), and may have been more effective if applied earlier.

Disease incidence and severity on 7 January 2013, 18 days after the final sprays, had, in general, declined to lower levels than observed on 14 December. Disease incidence and severity progress curves are shown in Appendix 2. At a final assessment on 21 February, diseases levels had declined further (data not presented).

Novel fungicides

It is noteworthy that all four novel products (two fungicides and two biofungicides), and also Fenomenal and Previcur Energy applied as foliar sprays under an Experimental Permit, resulted in useful reductions in disease severity. This indicates there is potential for six new products to be used as foliar sprays for control of downy mildew on ornamentals; it is understood that label and/or EAMUs are being sought for use on ornamentals for some of these products. Discussion with product suppliers indicate that Fenomenal is best used early in a programme as a preventative treatment, and that Previcur Energy will perform better in curative circumstances. Also, that Previcur Energy has better crop safety on ornamental crop compared with Fenomenal.

The product Infinito (flupicolide + propamocarb) is currently (February 2013) permitted for use on both outdoor and protected ornamentals under the Long Term Arrangements for

Extension of Use (LTAEU) by extrapolation from other crops, while EAMU applications for these uses are being considered (see Table 2). Potentially this is a very useful product for downy mildew control as it contains two active ingredients, both of which are active against downy mildew diseases, thereby reducing the risk of resistance development; and one of the actives (flupicolide) is in a novel mode of action group (Group 43) compared with the other fungicides used for downy mildew control (see Table 2).

Other downy mildew fungicides used in this work that also contain two active ingredients both with activity against downy mildews are Fubol Gold, Fenomenal, Percos, Previcur Energy and F62.

Foliar fertiliser

Hortiphyte (potassium phosphite) applied every 14 days as a foliar fertiliser gave incidental control of downy mildew at a level equivalent to that of many of the fungicides tested.

In this work Hortiphyte (6:31:11 w/v N:P:K) was applied at 2.5 L/ha in a spray volume of 1,000 L/ha (i.e. 2.5 ml product/L). A recent review of the use of phosphonates (another name for phosphites) to manage foliar potato late blight (*Phytophthora infestans*, an oomycete like downy mildew) concluded that rates of approximately 2.5 g a.i./L produced efficacy similar to that of the conventional contact fungicides mancozeb and chlorothalonil used at similar rates (Kromann *et al.*, 2012). The rate used in our work was less than that found effective on potato blight. Possibly more effective control could have been obtained with a higher rate, but there is a risk of crop damage with high rates used repeatedly. The Hortiphyte label recommends a rate of 1 L/ha for pot and bedding plants, 3 L/ha for hardy nursery stock and 4 L/ha for trees, with treatment every 3 weeks (pot and bedding) or monthly (hardy nursery stock).

Novel biofungicides

The two biological products (F60 and F61), although the least effective of treatments excluding Plant Trust (which was applied later than all other treatments) resulted in useful and significant reductions in downy mildew. It is understood that these products will be submitted for registration in the UK as biofungicides. Both products are also known to have activity against some other common diseases of ornamentals. The availability of biofungicides with activity against downy mildew will permit a reduction in the use of synthetic fungicides for control of downy mildew. Once such products are registered, further work will be required to determine how best to combine the use of biofungicides and fungicides in spray programmes.

Label approvals

In this study, Fenomenal was used as a high volume spray under an Experimental Permit following the Belgium label recommended rate for use against lettuce downy mildew (*Bremia lactucae*). There is no approval for use of Fenomenal as a high volume spray in the UK. Similarly, Previcur Energy was used as a spray under an Experimental Permit, as in the UK it is only permitted as a drench treatment on ornamentals. These two products were examined as sprays rather than as drenches because spray application is much more practical and cost-effective than drench application for growers to apply. HDC are considering submitting EAMU applications for CRD to evaluate the possible use of these products as sprays. The label recommendations should always be checked.

Plant vigour

When assessed on 1 November after five sprays of fungicides, *Geum* plant vigour was significantly reduced ($p < 0.001$) by the Plant Trust incorporation treatment (Table 7), and appeared to be reduced by one biofungicide (F60). Both these treatments resulted in control of downy mildew so the poor quality scores were not due to this disease. The poor quality of *Geum* plants in Plant Trust was due to the delayed potting of this treatment, around one month after all other plants. The biofungicide F60 was found to reduce plant quality when evaluated for control of brassica downy mildew (*Hyaloperonospora parasitica*) in the Sceptre project (CP 77). Plants treated with Fubol Gold had the greatest plant vigour, although this was not significantly better than the untreated control.

Phytotoxicity

A few *Geum* plants scattered throughout the trial developed patches of leaf yellowing on one or two leaves, first noted on 7 January 2013, three weeks after the final spray. Symptoms were suggestive of a chimaera (Fig 3). By 5 February 2013, there were greater numbers of affected plants and it was evident there was a treatment effect (Table 7). No symptoms occurred on untreated plants. Symptoms occurred quite commonly on plants treated with F61 (47% plants), Infinito (41%) and F62 (18%), and on less than 5% of plants treated with Percos, Pergado Uni, Previcur Energy, Hortiphyte and Paraat. Given that this symptom did not occur during September-December when the sprays were applied, and that a minimum of 7 applications were made with each product, it seems possible that the damage resulted from an interaction of treatment and an environmental factor, such as frosty weather. Periods of very cold weather occurred in December and January (Appendix 3).

Figure 3. Patches of leaf yellowing developed on *Geum* plants in early 2013 following frosty weather and earlier treatment with F61, F62 and Infinito.

Table 5. Effect of fungicides, biofungicides and a foliar fertiliser on *Geum* downy mildew disease incidence, Norfolk – 2012/13

Treatment	Mean % plants affected				
	20 Sep	18 Oct	15 Nov	14 Dec	7 Jan
1. Untreated	59	83	95	94	81
2. Fubol Gold	34	47	47	34	38
3. Signum	38	56	53	41	38
4. Fenomenal	56	63	65	50	38
5. Infinito	34	53	63	59	41
6. Percos	53	72	47	53	41
7. Pergado Uni	22	63	59	63	41
8. Previcur Energy	34	56	59	53	38
9. Hortiphyte	38	59	53	53	53
10. Paraat	38	69	63	75	66
11. F62	47	53	47	44	44
12. F60	28	63	75	81	59
13. F61	31	59	69	66	53
14. Plant Trust[a]	-	94	94	72	63
Significance (43 df)	0.013	<0.001	<0.001	<0.001	<0.001
LSD vs untreated	24.6	22.3	15.5	17.1	17.1
between treatments	28.4	25.7	17.9	19.7	19.7

[a] Plants potted into amended growing medium on 27 September.

Table 6. Effect of fungicides, biofungicides and a foliar fertiliser on *Geum* downy mildew disease severity, Norfolk – 2012/13

Treatment	% leaf area affected				
	20 Sep	18 Oct	15 Nov	14 Dec	7 Jan
1. Untreated	3.7	3.2	3.8	3.6	2.3
2. Fubol Gold	1.5	1.1	0.8	0.5	0.5
3. Signum	1.4	1.4	0.9	0.5	0.6
4. Fenomenal	2.2	1.4	1.1	0.8	0.5
5. Infinito	1.4	1.4	1.3	1.1	0.5
6. Percos	3.3	1.8	0.8	0.8	0.5
7. Pergado Uni	0.6	1.5	1.3	1.1	0.5
8. Previcur Energy	1.2	1.2	0.8	0.8	0.5
9. Hortiphyte	2.1	1.5	0.9	0.8	0.7
10. Paraat	0.9	2.0	1.2	1.4	1.1
11. F62	2.8	1.4	0.9	0.8	0.7
12. F60	1.5	2.1	1.6	1.7	1.1
13. F61	1.3	1.3	1.4	1.3	1.0
14. Plant Trust[a]	-	2.6	2.1	1.3	0.8
Significance (43 df)	<0.001	<0.001	<0.001	<0.001	<0.001
LSD vs untreated	1.62	0.62	0.99	0.82	0.82
between treatments	1.87	0.72	1.15	0.94	0.94

[a] Plants potted into amended growing medium on 27 September.

Table 7. Effect of fungicides, biofungicides and a foliar fertiliser on *Geum* plant quality (1 November 2012) and leaf yellowing (5 February 2013)

Treatment	Mean plant vigour score (1-9)		% *Geum* plants with leaf yellowing
	Geum	*Hebe*	
1. Untreated	7.1	8.4	0
2. Fubol Gold	8.2	8.5	0
3. Signum	7.8	8.8	0
4. Fenomenal	7.8	8.8	0
5. Infinito	7.8	9.0	41 (45)
6. Percos	7.5	8.5	5 (2.1)
7. Pergado Uni	7.8	7.8	2 (1.3)
8. Previcur Energy	7.3	7.5	3 (1.6)
9. Hortiphyte	7.0	8.8	1 (0.9)
10. Paraat	7.0	8.5	3 (1.6)
11. F62	7.3	8.0	18 (3.6)
12. F60	5.8	8.5	0
13. F61	7.5	8.0	47 (4.6)
14. Plant Trust	2.5	7.0	0
Significance (43 df)	<0.001	0.022	<0.001
LSD vs untreated	1.523	0.92	-
between treatments	1.758	1.06	-

( ) – standard error.

Experiment 3 – Fungicide programmes for control of Hebe downy mildew

The programmes examined in this experiment were designed to evaluate:

1. The potential of Plant Trust growing medium incorporation applied once at potting (for *Pythium* and *Phytophthora* control) to control downy mildew, and the duration of protection;
2. The efficacy of Fenomenal applied as a drench at monthly intervals compared with application as a high volume spray at the same timings;
3. A comparison of three simple programmes, each alternating two products every 14 days for control of downy mildew;
4. The incidental effect of a foliar fertiliser (Hortiphyte) applied at monthly intervals on downy mildew.

Control of downy mildew

Downy mildew was first observed on a few plants in week 37, two weeks after the start of the experiment. The disease remained at trace levels until week 46 (12 November) when obvious downy mildew was noted on several plants in one plot of T1 (untreated) and one of T2 (Plant Trust). At this stage there had been three monthly applications (treatments 3, 4 and 8) and six fortnightly applications (treatments 5, 6 and 7). This result indicates that the effect of Plant Trust was declining at 3 months after potting. This period is not dissimilar from the 'up to 5 months' claimed protection against *Phytophthora cinnamomi*.

One week later, the disease was obvious on many plants in most of the replicate plots of untreated plants and Plant Trust treated plants, and was beginning to appear in treatment 8 (Hortiphyte sprays applied monthly).

By week 49, when there had been four applications in T3, T4 and T8, and eight applications in T5-T7, downy mildew was still restricted to treatment 1 (untreated), 2 (Plant Trust) and 8 (Hortiphyte sprays).

A final assessment of downy mildew incidence and severity was done on 7 January, three weeks after the final treatment applications. Downy mildew then affected over 75% of plants in Treatment 1-4 and 8 (Table 8), albeit that the disease was present at very low levels in three of the treatments. It was not possible to assess downy mildew in treatments 5-7 at this stage due to severe leaf damage associated with four applications of Fubol Gold treatment, one more than the label maximum (see below – phytotoxicity). The incidence of downy mildew affected plants was reduced ($P < 0.001$) from 81% (untreated) to 73% by monthly sprays of Hortiphyte.

Downy mildew severity appeared to be reduced from 14.3% leaf area affected on untreated plants to less than 3% by monthly drenches of Fenomenal, and by monthly sprays of Fenomenal and Hortiphyte. Fenomenal applied as a high volume spray over plants at monthly intervals resulted in a similar low level of downy mildew (<2% leaf area affected) as plants drenched at the same timings. Plant Trust, at 20 weeks after incorporation, also appeared to have reduced the disease, with 7.8% leaf area affected. Unfortunately the variation within the experiment was large and there were no statistically significant differences between treatments when T5-T7 were excluded ($P > 0.05$). The lack of significant differences was due to the large differences between blocks for the untreated plots.

There were no symptoms of downy mildew in treatments 5, 6 and 7 until week 50, when the disease was noted in one plot of treatment 7. This observation indicates that the damage recorded on 7 January at the final assessment was predominantly due to accumulated phytotoxicity from Fubol Gold and not from downy mildew.

Phytotoxicity

Slight leaf scorch was first observed on occasional plants in one plot in treatments 3 and 4 (Fenomenal) in week 40, when three sprays had been applied. By week 45, leaf marking was obvious on several plants in treatments 2, 3 and 4. This result indicates possible damage from Plant Trust and Fenomenal on this variety of *Hebe*.

At week 47 leaf tip discolouration was evident on all plants in treatments 5, 6 and 7, where a common factor was use of Fubol Gold. At this stage, there had been three sprays of this product equal to the label maximum. The pale leaf colour on plants treated with Fubol Gold worsened over time and shoot tip dieback developed (Figures 4-5). By week 50 a few plants had collapsed (see Appendix 1). By 7 January 2013, three weeks after the fourth spray of Fubol Gold in T5-T7, most plants in these treatments were unsaleable (Table 9).

The distribution of plant quality scores (Table 10) clearly shows the adverse effect of Fubol Gold, with many plants in categories 1 and 2. The beneficial effect of Plant Trust, Fenomenal and Hortiphyte is shown by the greater proportion of plants in categories 3, 4 and 5 compared with the untreated.

The report author was unaware of any instances of crop damage from Fubol Gold when the treatments in this project were devised. Damage was seen on *Hebe* 'Frozen Flame' and not on *Hebe* x franciscana 'Variegata' or on *Geum* when used at the same rate. If the association of Fubol Gold with crop damage is truly causal, as seems probable, then this risk varies with crop species and variety. Of the two active ingredients in Fubol Gold, mancozeb is reported to have an excellent record of crop safety over a wide range of crops and environmental conditions (Gullino *et al.*, 2010). This suggests that the damage on *Hebe* 'Frozen Flame' was due to the metalaxyl-M component of the product. The dieback of shoot tips and pale discolouration of most leaves on treated plants was suggestive of a systemic effect, and metalaxyl-M is a systemic fungicide. It is known that another fungicide (azoxystrobin, e.g. Amistar) can cause damage on small leaved *Hebe* and rarely on large leaf *Hebe*, which is consistent with the difference between varieties observed with Fubol Gold.

Further enquiry determined that damage has previously been seen on seedlings of antirrhinum, marigold and New Guinea impatiens treated with Fubol Gold. It is

recommended that growers test a small number of plants before using Fubol Gold on a new species or variety for the first time, and do not exceed the label maximum of three spray applications. In situations where Fubol Gold does not cause crop damage, and providing the downy mildew on the host crop is not resistant to metalaxyl-M, this fungicide is generally very effective in controlling downy mildew, as demonstrated in the trial on *Geum*.

Table 8. Effect of fungicide programmes on *Hebe* downy mildew – Worcs, 7 January, 2013

Treatment	Application method	% plants affected	Mean % leaf area affected
1. Untreated	-	81 (3.0)	14.3
2. Plant Trust	Incorporated	89 (2.3)	7.8
3. Fenomenal	Drenches	82 (2.9)	1.6
4. Fenomenal	Sprays	86 (2.6)	1.0
5. Fenomenal/Fubol Gold	Sprays	-	-
6. Signum/Fubol Gold	Sprays	-	-
7. Hortiphyte/Fubol Gold	Sprays	-	-
8. Hortiphyte	Sprays	78 (3.2)	2.7
Significance (12 df)		<0.001	0.415
LSD		-	16.6

( ) – standard error.

Figure 4. *Hebe* ‘Frozen Flame` from Experiment 3 comparing untreated plants (left) and plants treated with four sprays (1 more than the label maximum) of Fubol Gold (right) – January 2013.

Figure 5. Close up of *Hebe* ‘Frozen Flame’ leaf damage after four sprays with Fubol Gold.

Table 9. Effect of fungicide programmes on plant quality, Worcs - 7 January 2013

Treatment	Application method	Mean plant quality score (0-5)	Proportion plants saleable (%)
1. Untreated	-	2.7	75 (4.0)
2. Plant Trust	Incorporated	3.0	84 (3.5)
3. Fenomenal	Drenches	3.2	97 (1.8)
4. Fenomenal	Sprays	3.3	100
5. Fenomenal/Fubol Gold	Sprays	1.8	0
6. Signum/Fubol Gold	Sprays	1.8	3 (1.8)
7. Hortiphyte/Fubol Gold	Sprays	2.3	25 (3.9)
8. Hortiphyte	Sprays	3.2	97 (1.9)
Significance (21 df)		0.002	<0.001
LSD		0.84	-

( ) – standard error.

Table 10. Distribution of *Hebe* plant quality scores, Worcs – 7 January 2013

Treatment	Total number plants with quality score				
	1	2	3	4	5
1. Untreated	5	3	22	2	0
2. Plant Trust (incorporation)	1	4	24	1	2
3. Fenomenal (drench)	0	1	25	4	2
4. Fenomenal (spray)	0	0	26	3	3
5. Fenomenal/Fubol Gold	8	24	0	0	0
6. Signum/Fubol Gold	8	23	1	0	0
7. Hortiphyte/Fubol Gold	3	21	4	3	1
8. Hortiphyte	0	1	27	2	2

Conclusions

1. *Geum* downy mildew (*Peronospora potentillae*) was reduced by high volume sprays of the fungicides Signum (boscalid + pyraclostrobin), Previcur Energy (propamocarb + fosetyl aluminium), Infinito (flupicolide + propamocarb), Fubol Gold (metalaxyl + mancozeb), Paraat (dimethomorph), Pergado Uni (mandipropamid), Fenomenal (fosetyl aluminium + fenamidone), Percos (ametoctradin + dimethomorph), one novel fungicide product (F62), the foliar fertiliser Hortiphyte (potassium phosphite) and two novel biofungicides (F60 and F61); and by growing medium incorporation of Plant Trust (fosetyl aluminium).

2. There was a trend for reduced *Hebe* downy mildew (*Peronspora grisea*) with Fenomenal applied monthly as a drench or as a high volume spray, by Hortiphyte applied monthly as a spray and by incorporation of Plant Trust in the growing medium.
3. Evidence was gained that Fenomenal used as a high volume spray can control downy mildew diseases; an application to CRD to permit such use in the UK should be considered.
4. A glasshouse crop of *Hebe* 'Frozen Flame' was damaged by high volume sprays of Fubol Gold at 1.9 g/L, with leaf tip pale discolouration appearing after three sprays, and leaf scorch, shoot dieback, poor colour and occasional plant collapse when applied more than the label maximum of three sprays.
5. A polytunnel crop of *Hebe* x fransciscana 'Variegata' was not damaged by nine high volume sprays of Fubol Gold at 1.9 g/L.
6. Multiple applications of Infinito, F61 and F62 followed by cold weather were associated with patches of leaf yellowing on *Geum*.

References

Kronmann P, Perez WG, Tarpe A, Schulte-Geldermann E, Sharma BP, Andrada-Peida JL & Forbes GA (2012). Use of phosphonates to manage potato late blight in developing countries. *Plant Disease* **96**, 1008-1015.

Gullino ML, Tinivella F, Garibaldi A, Kemmitt GM, Bacci L & Sheppard B (2010). Mancozeb – past, present and future. *Plant Disease* **94**, 1076-1087.

Technology transfer

Presentations

Control of downy mildew on shrubs and herbaceous plants. Herbaceous Perennials Technical Discussion Group, London, 21 February 2013 (Tim O'Neill)

Sceptre – filling crop protection gaps and application to ornamentals. British Protected Ornamentals Association Conference, Oxford, 6 February 2013 (Tim O'Neill)

Article

O'Neill TM (2013). Increasing downy mildew control options. *HDC News* (in press).

Appendix 1 – Crop diaries

Crop diary – Norfolk

Week number	Observation/action
36	Trials set up, spray 1 applied (all treatments)
37	Spray 2 (all treatments)
38	Spray 3 (all treatments)
39	Spray 4 (biologicals). T14 (Plant Trust) set up
40	Spray 5 (all treatments)
41	Spray 6 (biologicals)
	Hebe 'infector plants' introduced (1 Oct)
42	Spray 7 (all treatments)
43	Spray 8 (biologicals)
44	Spray 9 (all treatments)
45	Spray 10 (biologicals)
46	Spray 11 (all treatments)
47	Spray 12 (biologicals)
48	Spray 13 (all treatments)
49	Spray 14 (biologicals)
50	Spray 15 (all treatments)
51	Spray 16 (biologicals)
2	Disease assessment (3 weeks after final spray)
6	Assessment of yellowing in *Geum*
8	Trial concluded. Disease assessment (9 weeks after final spray)

Crop diary – Worcs

Week number	Action/Observation
34	Plants potted. T2 into Plant Trust amended compost.
35	Trial laid out. First application of treatments (T3-T8).
37	Plants rooting out well from liners.
	Downy mildew noted on one plant, plot 28 (T4).
	Second application of treatments (T5-7).
38	Possible mildew symptoms on several plants.
	Leaves browning on 1 plant in T7 (plot 1).
39	Third application of treatments (T3-T8).
	Possible mildew in several plots (T1, 3, 4, 5, 6, 7).
40	All plants have made good new growth. Scorch on occasional plant in plots 9 (T3) and 28 (T4).
41	Fourth application of treatments (T5-7).
42	Leaf scorch on occasional plants in plots 7 (T6), 9 (T3), 11 (T4), 14 (T8), 20 (T3), 28 (T4) and 29 (T5).
43	Fifth application of treatments (T3-T8).
	Trace of caterpillar damage.
44	Leaf scorch/tip dieback, as in week 42. Severe on one plant in plot 31 (T6).
	Trial assessed by T O'Neill. No downy mildew found.
45	Sixth application of treatments (T5-7).
	Leaf marking on several plants in plot 2 (T4), plot 3 (T2), plot 9 (T3), plot 28 (T4).
46	Severe leaf scorch in plot 9 (T3).
	Obvious downy mildew on 13 plants in plot 27 (T1) and 30 (T2).
47	Seventh application of treatments (T3-T8).
	All reversion pruned out.
	Downy mildew obvious in plots 10 (T2), 22 (T11), 23 (T2), 26 (T8), 27 (T1), 30 (T2).
	Leaf tip discolouration on all plants in T5, T6 and T7.
48	Downy mildew obvious in plots 22 (T1), 23 (T2), 26 (T8), 27 (T1), 30 (T4).
	Light green leaf tip on all plants, some with scorch, in plots 6 (T5), 8 (T6), 12 (T7), 15 (T5), 16 (T6), 18 (T6), 19 (T7), 21 (T5), 29 (T5), 31 (T6), 32 (T7).
49	Eighth application of treatments (T5-7).
	Downy mildew obvious in plots 5 (T8), 10 (T2), 13 (T1), 22 (T1), 23 (T2), 26 (T8), 27 (T1), 30 (T2).

	Obvious scorch and poor colour in plots 6 (T5), 8 (T6), 12 (T7), 18 (T6), 19 (T7), 21 (T5), 31 (T6), 32 (T7).
50	As above. Downy mildew also in plot 2 (T4), 19 (T7).
	Plant collapse in plot 6 (T5).
51	Ninth (final) application of treatments (T3-T8).
	Downy mildew and scorch as above.
2	Final assessment – disease and plant quality (D Talbot).

Appendix 2 – Geum downy mildew disease progress charts

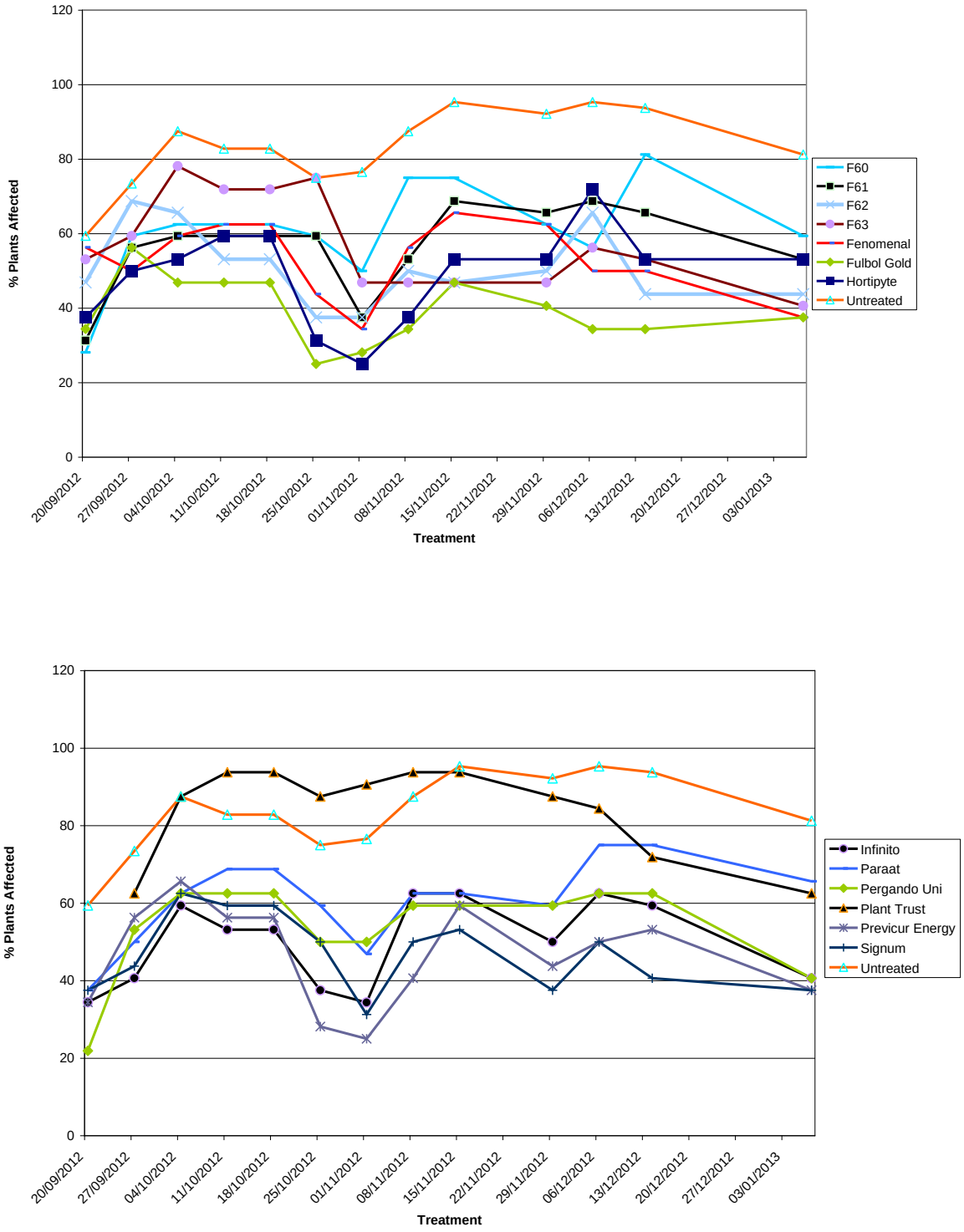

Figure 5. Effect of treatments on incidence of *Geum* downy mildew – 2012

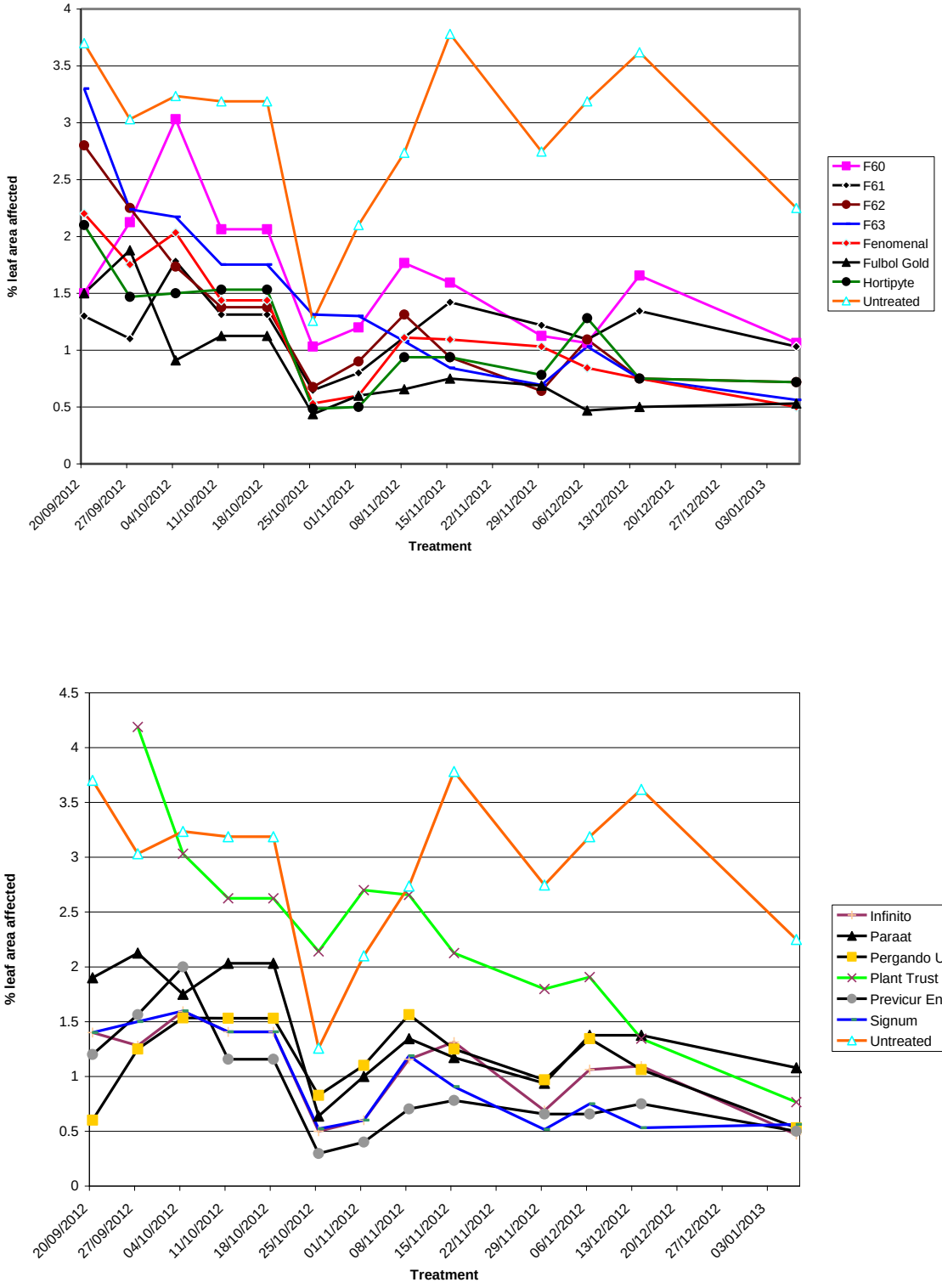

Figure 6. Effect of treatments on severity of *Geum* downy mildew – 2012

Appendix 3 – Geum & Hebe downy mildew logger temperature data

Month	Max of Celsius(°C)		Min of Celsius(°C)		Average of Celsius(°C)		Average of Humidity(%rh)	
	Geum	*Hebe*	*Geum*	*Hebe*	*Geum*	*Hebe*	*Geum*	*Hebe*
September	35.5	35.5	4.5	5.0	14.5	14.6	79.4	76.7
October	23.0	23.0	0.5	0.5	10.6	10.9	89.0	86.8
November	17.5	17.5	-0.5	0.0	6.8	7.1	94.8	92.5
December	12.0	12.0	-2.5	-1.5	4.7	5.2	96.0	94.2
January	13.5	14.5	-4.5	-2.5	3.6	4.1	96.6	95.5
February	15.5	18.5	-2.0	-1.5	3.5	4.1	92.2	90.3