Final Report (March 2000)

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AUTHENTICATION

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

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PRACTICAL SECTION FOR GROWERS

Objectives and background

Hebe downy mildew, caused by the fungus *Peronospora grisea,* is a common and very damaging disease affecting many commonly grown Hebe varieties. It occurs on both outdoor and protected crops, but is particularly damaging in the summer and autumn in crops grown with overhead irrigation. It causes leaf yellowing, poor growth and leaf distortion and severe attacks can render plants unmarketable. Effective control on a susceptible variety requires an intensive spray programme, especially in a high-risk growing environment (i.e. intense cropping, polythene tunnel, overhead irrigation). Leaves of many susceptible varieties (e.g. Midsummer Beauty) are shiny and difficult to wet and this may in part explain the difficulty in controlling the disease.

The **commercial objective** of the proposed work is to evaluate new fungicides in comparison with the current standard products, and to develop a spray programme which provides effective and reliable control of Hebe downy mildew.

Summary of results

First year (1997)

Nine fungicide treatments and a resistance elicitor were evaluated on container-grown plants of Hebe x franciscana 'Variegata' grown in two unheated polythene tunnels on a commercial nursery in Norfolk. Fungicides were applied as high volume sprays every 14 days to small plants badly affected by downy mildew (Experiment 1) and to older plants slightly affected by downy mildew (Experiment 2). In Experiment 1, downy mildew developed on new growth but remained at a relatively low level. Severity of the disease on new growth was significantly reduced (65-90%) by all treatments including two novel fungicides (strobilurins) and a resistance elicitor. Invader and Amistar resulted in the greatest proportion of plants (47%) with healthy new growth at the end of the trial. In Experiment 2, where downy mildew was slightly more damaging, the disease was reduced by all treatments with Aliette the most effective (*c.* 50% disease reduction). The resistance elicitor was phytotoxic after repeated treatments resulting in leaf yellowing and premature fall. The amount of spray deposit visible after treatment varied with fungicides. Aliette at the lower rate and Amistar left little deposit while Bravo, Elvaron, Invader and Ripost Pepite left an obvious white deposit.

Second year (1998)

A preliminary experiment was undertaken to investigate the effect of water volume on leaf coverage when spraying container-grown plants, spaced in beds so that leaves of adjacent plants were just touching. The proportion of leaf area wetted, determined using water-sensitive paper, increased greatly with water volume from 500 to 1,000 l/ha, but there was relatively little additional benefit when the volume was further increased up to 2,000 litres/ha. On the upper surfaces of leaves, spray coverage was consistently greater in the upper than mid or lower canopies (81.3, 67.5 and 36.3%) leaf area, respectively, at 1,000 l/ha. Spray coverage on the lower surface of leaves rarely exceeded 10% at any leaf position, or spray volume tested.

Eight fungicide programmes and four fungicide/adjuvant treatments were evaluated on Hebe x franciscana 'Variegata' grown in a low polythene tunnel with overhead sprinkler irrigation. Fungicides were applied at 1,000 l/ha, at intervals ranging from 7 to 28 days, from 31 July to 10

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September 1998. Natural infection by downy mildew occurred in early August and the disease increased to cause substantial damage on untreated plants between mid-August and mid-September.

By 8 September, downy mildew affected over 40% leaf area on untreated plants. This was reduced by all treatments and less than 10% leaf area was affected on five treatments. Amistar (2% leaf area infected) was the most effective. On 23 September, 21 days after the final spray for most treatments, the disease had increased to cover 55% leaf area on untreated plants. Amistar continued to provide very effective control. Aliette applied every 14 days gave significant but relatively slight control (38% leaf area affected) under the severe disease pressure. This was improved by alternating Elvaron and Bravo between the Aliette sprays, such that a treatment was made every 7 days. A 14 day alternating programme of Aliette, Invader, Ripost Pepite and Amistar gave good control, almost equal to Amistar. Extending the spray interval of Aliette from 14 to 28 days resulted in poorer control than the 14 day programme, even though a high rate (5 g/litre) was used. Codacide appeared slightly to improve the efficacy of Aliette (used at 2.5 g/litre every 14 days). However, at a lower rate of Aliette neither Codacide nor Silwet L77 improved the control given by the fungicide. A 14 day alternating programme of Aliette and Favour 600 SC gave relatively poor control of downy mildew.

A marked edge effect occurred in the trial, with very little downy mildew visible in the two extreme, outer rows of plants and at one end of the tunnel where it appeared likely there was greater air movement (these plants were omitted when determining final treatment efficacy). This pattern of infection strongly suggests that air movement (or lack of it) is a key determinant affecting downy mildew development.

Third year (1999)

Five fungicide programmes were evaluated on Hebe x franciscana 'Variegata'. The treatments were tested in two low polythene tunnels with overhead irrigation. One was arranged with poor ventilation (end door partly open) and a second with fan-assisted ventilation. Fungicides were applied at 1,000 l/ha at intervals of 14 days, or 7 days (2 programmes), from 1 July to 7 October. In each tunnel 4 replicate blocks of plants were spaced as soon as leaves of adjacent plants touched (early spacing - 5 August) or later than good practice ('late spacing' - 16 September). Natural infection by downy mildew was present on around 40% of plants when the trials were established, affecting 1-2% leaf area.

The disease increased steadily on untreated plants over the next 4 months and by 7 October affected 31-35% leaf area. This was reduced by all fungicide programmes with four of them resulting in less than 10% leaf area affected. A programme of Amistar/Amistar/Invader/Ripost (T6) applied initially at 14 day intervals and reducing to 7 day intervals from 5 August was the most effective, resulting in less than 4% leaf area damage. On 21 October, when the top 10 cm of growth was assessed, this treatment had reduced downy mildew to an average of 1% leaf area affected with many plants completely free of the disease. Programmes of Amistar/Amistar and Amistar/Amistar/Invader /Ripost applied at 14 day intervals, and Aliette/Elvaron/Aliette/Bravo at 7 day intervals, were only slightly inferior to the most effective treatment (T6). A 14 day programme of Aliette/Favour gave significant disease control but was less effective than other treatments.

Timing of plant spacing had a slight but statistically significant effect on disease severity, with less disease on plants spaced early. On untreated plants the rate of disease progress was greater in the poorly ventilated tunnel than that with fan-assisted ventilation for most of the season. Measurement of relative humidity revealed no consistent difference between the two tunnels.

Plant quality at the end of the trial (21 October) was significantly influenced by fungicide treatment with the best quality plants occurring where fungicide treatment gave good downy mildew control. The % of unmarketable plants was reduced from 71.4% (untreated) to 0% by the Amistar/Amistar /Invader/Ripost programme (average of both tunnels). High quality showed as several evenly sized branches free or virtually free of downy mildew and an increased plant height (by around 10 cm). There was no-evidence of plant damage as a result of fungicide application on this variety from any of the treatments.

Action points for growers

Spray Coverage

1. Spray coverage is likely to increase with water volume but the increase will become progressively less above a certain value. We found 1,000 l/ha (100 ml/m^2) was appropriate to treat small plants (c. 20 cm tall). Consider using water-sensitive paper to check the coverage achieved with your sprayer.

2. Very little spray was deposited on the lower surface of leaves when spraying from above. Alternative spray application systems (e.g. from the side; air-assisted) may be more effective.

Growing environment

3. Hebe plants grown in a low (2.7 m), unheated polythene tunnel and irrigated by overhead sprinklers became severely affected by downy mildew. Where possible, select crop species/varieties that are resistant to downy mildew for such growing environments.

4. The pattern of disease in the year 2 trial strongly suggested air-movement can have a major effect on epidemic development. Good crop management (e.g. greenhouse ventilation, plant spacing) will become an increasingly important element in downy mildew control as plants increase in size and reach the edge of pots.

5. Spacing plants as soon as adjacent plants began to touch gave a small but statistically significant reduction in mildew, compared with later spacing. It also resulted in better final plant shape.

6. Growing plants in a fan-ventilated tunnel resulted in a slower rate of disease development than in an equivalent tunnel without fan ventilation.

Amistar

7. Amistar, a product in the new strobilurin group of fungicides, gave excellent control of downy mildew with no evidence of crop damage and very little spray deposit. When such products become available for use on Hebe, they should be considered for inclusion in a downy mildew spray programme. They should be used in conjunction with non-strobilurin fungicides (e.g. Aliette, Favour 600 SC, Ripost Pepite) to reduce the risk of selecting resistant strains of *P. grisea* (see below).

8. Use of Amistar is permitted on outdoor Hebe, at growers own risk. Use on crops under protection is not permitted at present.

9. The safety of Amistar to Hebe varieties other than x franciscana 'Variegata' has not been assessed. Growers should test treat a few plants before using it widely on a crop.

Aliette

10. High volume sprays of Aliette at 1.25 g/l (1.25 kg/ha) were only slightly inferior to 2.5 g/l (2.5 kg/ha). Both rates reduced downy mildew by more than 60% 1 week after the final spray but disease control was considerably less 3 weeks after the final spray. Maintain a spray programme (e.g. every 7 -10 days) in order to maintain control during conditions favourable to downy mildew. Previous work on rose downy mildew (HNS 53) indicated there was no substitute for preventative treatment.

11. When Aliette was applied at a high rate at monthly intervals, the greater quantity of chemical applied did not compensate for the extended spray interval. Spray timing appears to be critical; a warning system is not yet available.

Fungicide programme

12. A programme of Amistar/Amistar/Invader/Ripost applied initially at 14 day intervals and reducing to 7 days as the disease began to increase gave the best control in the year 3 trial (88 - 98% control). Maintaining the spray interval at 14 days was only slightly less effective.

13. Alternating programmes of Aliette/Amistar (every 14 days) and Aliette/Elvaron/Aliette/Bravo (every 7 days) gave control almost equal to that of the Amistar/Amistar/Invader/Ripost programme.

14. An alternating 14 day programme of Aliette/Favour provide 44 - 66% control, but this was less effective than the other 14 day fungicide programmes.

Spray adjuvants

15. The influence of Codacide on the effectiveness of Aliette varied with concentration of the fungicide. There was a benefit at 2.5 g/l but not at 1.25 g/l. Silwet L77 did not improve effectiveness of the fungicide at either rate. The benefit of using an adjuvant with Aliette on Hebe is not proven; be wary of cutting the fungicide rate if you do use an adjuvant.

Avoiding fungicide resistance

16. The Fungicide Resistance Action Committee (FRAC) have issued the following guidelines to minimise the risk of resistance arising to Amistar and similar strobilurin fungicides:

    1. Strobilurins should be used where possible as preventative treatments.
    2. Strobilurins should be applied at the manufacturer's recommended rates.
    3. Strobilurins should not constitute more than 30% to 50% of the total number of fungicide applications made to the crop in one season (*strobilurin spray numbers should move to the lower limit when the total number of fungicide sprays made to the crop exceeds 8).*
    4. Strobilurins should be used in blocks of 1 to 3 consecutive applications.
    5. Where blocks of 2 or 3 strobilurins are applied they should be separated by a minimum of 2 applications of a fungicide from a different cross-resistance group.
    6. For perennial crops or where crops are grown successively, alternation of programmes should continue between seasons and between crops respectively.

Notes

- A maximum of 2 consecutive applications of 'Amistar' should be made to a crop
- These recommendations apply to strobilurins used alone or in formulated or tank mixture with chemicals from other fungicide groups designed to increase the level or spectrum of disease efficacy.

17. If a general spray programme includes use of Bravo 500 and/or Elvaron WG interspersed between more specific downy mildew products, these fungicides will provide additional protection against downy mildew. They will also reduce the risk of selecting downy mildew pathogens resistant to the more specific fungicides. Plan the spray programme carefully to maximise protection against downy mildew (e.g. treatment 3 in the year 2 and 3 trials.

Practical and anticipated financial benefits

The UK production of container-grown Hebe is believed to be in excess of 2 million plants per annum, with a value around £4 million. Downy mildew is the major disease problem affecting Hebe and it can severely affect the production of many varieties.

The current financial cost to the industry as a result of downy mildew is unknown, but it is believed to be significant both in terms of lost production and cost of fungicide sprays and their application. Complete crop loss can occur. Adoption of the action points above, together with current best practices for control of Hebe downy mildew, should ensure that losses to the disease are kept to a minimum.

SCIENCE SECTION

INTRODUCTION

Previous work on control of Hebe downy mildew showed that spray programmes based on Aliette, applied every 14 days at 1.5 kg/ha, gave good control of the disease on new growth in a crop where there was widespread infection when the first spray treatment was applied Programmes based on Favour 600 SC, Filex, Zineb, Galben M, Curzate M and Trustan were ineffective.

Work on rose downy mildew *(Peronospora sparsa)* identified Aliette and Ripost Pepite (= Trustan) as fungicides capable of providing good control of the disease when applied as spray treatments (HNS 53). Favour 600 SC, Fubol 75 WP and Ripost Pepite as spray treatments, and Aliette as a drench treatment, also gave good control of the same fungus on micropropagated blackberry plants.

Several new fungicides with activity against downy mildew fungi have recently been described. These include a new fungicide group (strobilurins) and 'plant activators' which induce systemic acquired resistance and are reported to be effective against downy mildew fungi.

There is increasing interest in the use of spray adjuvants when using pesticides. Various adjuvants are claimed to offer benefits in enhancing pesticide activity, improving pesticide cover and in reducing the amount of pesticide that needs to be applied. However, most of the published work on spray adjuvants has been with reference to arable crops. Furthermore, results from these trials have been very variable. Given the difficulty in wetting Hebe leaves and the need for frequent sprays, Hebe downy mildew is an appropriate disease to evaluate selected spray adjuvants.

In the first year of this project, we demonstrated partial control of downy mildew using a range of products applied at 14 day intervals, including Aliette, Amistar, Bravo 500, Elvaron, Favour, Invader, Ripost Pepite and an experimental strobilurin product. A 'plant activator' was partially effective but phytotoxic. Some products left a very obvious spray deposit (e.g. Bravo, Elvaron, Invader, Ripost Pepite), whilst other (Aliette at 1 g/litre, Amistar) left very little visible deposit.

In the second year we demonstrated 1,000 l/ha to be the spray volume giving greatest coverage of small (20 cm tall) Hebe plants, though little was deposited on lower leaf surfaces. Of eight fungicide programmes tested from 31 July to 10 September, Amistar at 14 day intervals gave outstanding control of downy mildew. Alternating programmes of Aliette, Invader, Ripost Pepite and Amistar (at 14 day intervals) and of Aliette, Elvaron, Aliette and Bravo (7 day intervals) gave good control. Two adjuvants applied to a low rate if Aliette did not improve disease control, though Codacide added to a high rate if Aliette (2.5g/litre) gave some benefits. The pattern of disease occurrence in the trial strongly indicated that air movement was a key determinant in preventing development of mildew.

The **specific objectives** in the third year are:

1. To test selected fungicide programmes for their effectiveness in controlling Hebe downy mildew.
2. To investigate the effects of timing of plant spacing on the development of downy mildew.
3. To monitor development of downy mildew in two polythene tunnels with contrasting ventilation.

For full details of the year 1 and 2 results, please see the Annual Reports of March 1998 and 1999.

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MATERIALS AND METHODS

Site and crop details

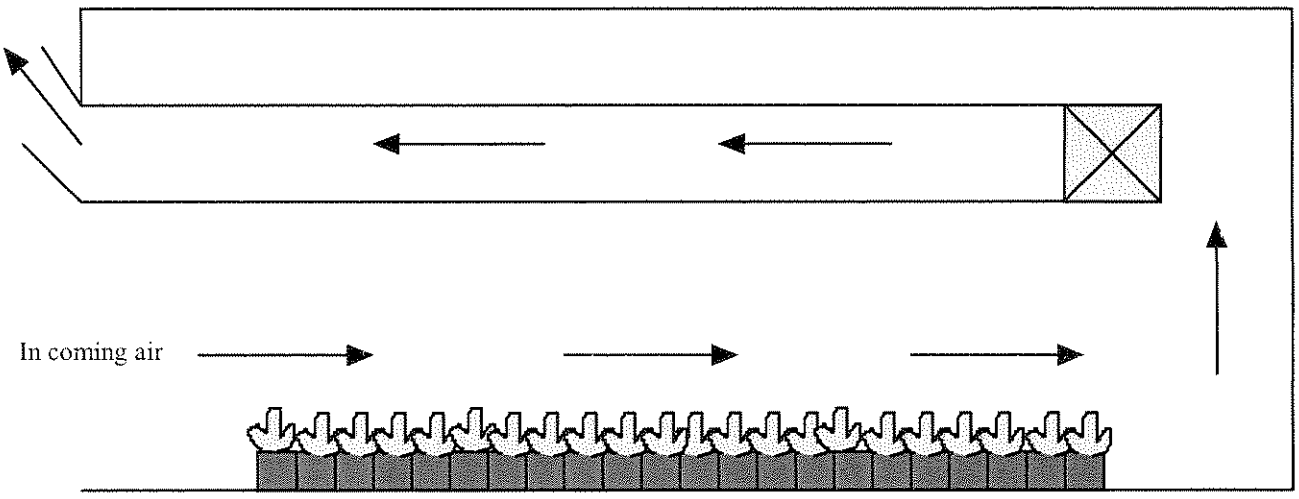
Experiments were carried out in two unheated walk-in, single span polythene tunnels on a commercial nursery (Darby Nursery Stock Ltd) in Norfolk. Small recently-potted plants (10 - 12 cm tall) of Hebe x franciscana 'Variegata', in 1 litre pots were used. Plants were stood on sand beds and watered from overhead, as required, by sprinkler irrigation with borehole water (pH 7.8). The tunnels were 18.2 m x 4.3 m in area (78.3 m²) and 2.7 m maximum height, with doors (1.8 m wide x 1.9 m high). In one tunnel ('poorly ventilated'), the sides of the tunnel were left closed and ventilation was through the top half of the of the end doors. In the second tunnel (fan ventilated), the tunnel was left with sides down and one end fully closed and ventilated by a Rite Air fan with polythene tube vent (Fig 1). Downy mildew was present at a trace level on around 40% of plants at the start of treatments.

Treatments

1. Untreated
2. Aliette at 2.5 g/litre alternating with Favour 600SC at 3 ml/litre every 14 days
3. Alternating programme of Aliette (2.5 g/litre), Elvaron (3 g/litre), Aliette (2.5 g/litre) and Bravo 500 (2.2 ml/litre) every 7 days
4. Alternating programme of Aliette (2.5 g/litre) and Amistar (1 ml/litre) every 14 days
5. Alternating programme of Amistar (1 ml/litre), Amistar (1ml/litre),Invader (2.5 g/litre) and Ripost Pepite (2.5 g/litre) every 14 days
6. As above, reducing to 7 days when downy mildew became obvious (from 5 August)

Sprays were applied as indicated from 1 July to 7 October The spray volume was 1,000 l/ha (100 ml/m²) applied using an Oxford precision sprayer operating at 2 Bar pressure with a medium flat fan nozzle (Lurmark 11003).

Figure 1. Fan ventilation of tunnel - Norfolk 1999



Assessments

Assessments were made on the central 6 plants in each plot of

- incidence of plants affected by downy mildew
- severity of the disease (% leaf area affected)
- phytotoxicity following fungicide application

At the final assessment (21 October), disease was assessed on the upper 10 cm of plants.

Plant quality was assessed using the following key:

1 - Severely stunted: many leaves affected by mildew (unmarketable)
2 - Stunted or badly shaped; many leaves with obvious mildew (unmarketable)
3 - Reasonable shaped. Mildew obvious but plant recoverable with severe trimming
4 - Good size and shape plant. 3 or more leaves affected by mildew in the top 10 cm.
5 - Good size and shape plant. Plant free or virtually free of mildew (1 - 2 leaves maximum)

Experiment design and analysis

Two identical experiments were carried out in polythene tunnels approximately 20m apart. One tunnel was poorly ventilated, the other fan-assisted.

Experiments were of a split-block design. Plots were randomised within blocks for fungicide treatment and blocks were randomised for spacing (early or late). There were four replicates of each fungicide treatment and eight replicates of the untreated. Plot size was 0.93 m x 0.75 m (0.7 m^2) and each plot consisted of 20 plants initially arranged pot-thick (4 x 5). Each tunnel contained 56 plots (7 treatments plots x 4 replicates x 2 spacings). No leaf trimming was done. Results were analysed by analysis of variance, after data transformation where necessary. Statistically significant differences between treatments are shown as:

* $P<0.05$; ** $P<0.01$; *** $P<0.001$ and NS = not significant ($P>0.05$)

Crop diary

Date	Action	Spray applications
01 July	Trial established	02 July (All)
07 July	Assessment 1	09 July (T3)
		15 July (All)
22 July	Assessment 2	22 July (T3)
		29 July (all)
05 August	Early spacing	05 August (T3 + T6)
12 August	Assessment 3	13 August (all)
26 August	Assessment 4	18 August (T3 + T6)
		26 August (all)
		02 September (T3 + T6)

Crop dairy continued.

Date	Action	Spray applications
		09 September (all)
16 September	late spacing	17 September (T3 + T6)
		23 September (all)
		1 October (T3 + T6)
7 October	Assessment 5	07 October (all)
		15 October (T3 + T6)
21 October	Assessment 6	21 October (all)

RESULTS

1. Disease progress

Downy mildew was present on around 40% of plants, affecting on average 1 - 2% leaf area, when the trials were established. Plants were distributed so that infected plants were spread evenly between and within the two tunnels. On untreated plants the severity of downy mildew increased steadily July and early August, affecting 20 - 30% leaf area by 26 August. The initial rate of disease increase (early July) was greater in the poorly ventilated tunnel than in that with fan-assisted ventilation (Fig 2).

2. Effect of fungicide programmes

All fungicide programmes significantly reduced disease development, in both the poorly ventilated and well ventilated tunnels (Table 1; Figs 3 - 4). The most effective treatment was Amistar/Amistar/Invader/Ripost (T6), applied initially at 14 day intervals and reducing to a 7 day interval from 5 August. By 7 October disease severity on untreated plants was 31 - 35% and less than 4 % where this programme was applied. With the exception of Aliette/Favour, which reduced downy mildew by 52 - 66% (poorly ventilated tunnel) and 44 - 59% (fan ventilated tunnel), the other fungicide programmes all reduced disease by 68 - 78 % (poorly ventilated tunnel) and 68 - 79 % (fan ventilated tunnel).

At the final assessment on 21 October, when the upper 10 cm of shoots were assessed, disease severity on this important area of the plant was around 1 % following treatment with Amistar/Amistar/Invader/Ripost (T6), and over 40% on untreated plants. Many of the fungicide treated plants in T6 had virtually no mildew visible on them (Table 1).

3. Timing of plant spacing

At both October assessments in the fan ventilated tunnel there was a slightly but significantly lower severity of downy mildew on plants spaced early (Table 1). Timing of plant spacing had little or no effect in the poorly ventilated tunnel

4. Plant quality

Plant quality on 21 October, assessed on a 0 - 5 index was significantly different between fungicide treatments, with the untreated plants of poorest quality (index 1.87 - 2.14) whilst plants treated with Amistar/Amistar/Invader/Ripost (T6) were of the greatest quality (index 4.23 - 4.29). The incidence of unmarketable plants (quality index 1 and 2) was reduced from 71.4% (untreated) to 0% by treatment 6 (average of both tunnels) (Table 2). The plants in treatment 6 were approximately 10 cm taller than those which received no fungicide sprays. There was no evidence of crop damage following application of fungicide sprays on this variety of Hebe.

5. Comparison of ventilation systems

Both tunnels were conducive to development of Hebe downy mildew. The fan-assisted ventilation appeared to reduce the rate of disease development slightly, especially up to 26 August, but there was little difference between tunnels at the final assessment (Table 1). Measurement of humidity, just above the crop canopy, revealed no consistent difference between the two tunnels (Table 3).

Table 1. Effect of fungicide programmes, plant spacing and tunnel ventilation on Hebe downy mildew -Norfolk 1999

Treatment	Mean % leaf area affected			
	Poorly ventilated		Fan ventilated	
	7 Oct	21 Oct[3]	7 Oct	21 Oct[3]
Fungicide[1]				
1. Unt	31.2	42.2	34.8	46.7
2. Ali/Fav	10.5	20.2	14.2	26.2
3. Ali/Elv/Ali/Bra (7d)	4.7	8.5	6.4	11.8
4. Ali/Ami	7.0	13.7	7.4	15.1
5. Ami/Ami/Inv/Rip	4.4	6.4	4.3	6.0
6. Ami/Ami/Inv/Rip (7d)	3.8	1.1	3.9	1.2
Significance	***	***	***	***
SED (19 df) between trts	3.19	5.13	5.31	7.36
unt vs trt	2.77	4.45	4.60	6.37
Spacing [2]				
Early	12.3	19.5	13.7	20.0
Late	14.1	18.9	16.5	23.9
Significance	*	NS	***	*
SED (3 df)	0.36	-	0.13	1.06

[1] All sprays applied at 14 d intervals except where indicated
[2] Spaced on 5 August (early) of 16 September (late)
[3] Top 10 cm of growth assessed

*** - statistically significant difference between treatments at $P < 0.001$
* - statistically significant difference between treatments at $P < 0.005$
NS - no significant differences

Table 1 cont.[d] Effect of fungicide programmes, plant spacing and tunnel ventilation on Hebe downy mildew - Norfolk, 1999

Treatment	Mean % leaf area affected			
	Poorly ventilated		Fan ventilated	
	7 Oct	21 Oct[3]	7 Oct	21 Oct
Fungicide[1] x spacing[2]				
Early				
1. Unt	30.0	43.7	32.0	40.7
2. Ali/Fav	8.0	19.3	11.5	23.8
3. Ali/Elv/Ali/Bra (7d)	3.8	7.8	6.3	14.0
4. Ali/Ami	6.2	13.9	6.3	14.0
5. Ami/Ami/Inv/Rip	4.5	6.6	4.0	5.2
6. Ami/Ami/Inv/Rip (7d)	3.9	1.3	4.0	1.3
Late				
1. Unt	32.3	40.8	37.5	52.6
2. Ali/Fav	12.9	21.1	16.9	28.6
3. Ali/Elv/Ali/Bra (7d)	5.6	9.2	6.5	9.7
4. Ali/Ami	7.8	13.6	8.5	16.1
5. Ami/Ami/Inv/Rip	4.3	6.2	4.6	6.9
6. Ami/Ami/Inv/Rip (7d)	3.7	0.8	3.9	1.0
Significance	NS	NS	*	NS
SED (19 df) trt vs trt	-	-	5.41	-
trt vs unt			4.67	
unt vs unt			3.80	

[1]All sprays applied at 14 d intervals except where indicated
[2] Spaced on 5 August (early) of 16 September (late)
[3] Top 10 cm of growth assessed

*** - statistically significant difference between treatments at $P < 0.001$
* - statistically significant difference between treatments at $P < 0.05$
NS - no significant differences

Table 2. Effect of fungicide treatment, plant spacing and tunnel ventilation on Hebe quality - Norfolk, 21 October 1999

Treatment	Final plant quality (0 - 5)		% plants unmarketable	
	Poorly ventilated	Fan ventilated	Poorly ventilated	Fan ventilated
Fungicide[1]				
1. Untreated	1.87	2.14	77.1	65.6
2. Ali/Fav	2.85	3.00	25.0	16.7
3. Ali/Elv/Ali/Bra (7d)	3.81	3.58	2.1	0
4. Ali/Ami	3.42	3.35	0	2.1
5. Ami/Ami/Inv/Rip	4.04	4.13	2.1	0
6. Ami/Ami/Inv/Rip (7d)	4.23	4.29	0	0
Significance	***	***	-	-
SED (19 df) between trts	0.162	0.309	-	-
	0.140	0.268	-	-
Spacing [2]				
1. Early	3.22	3.27	23.2	19.6
2. Late	3.09	3.19	29.2	23.2
Significance	NS	NS	-	-
SED (3 df)	-	-	-	-

[1] All sprays applied at 14 d intervals except where indicated
[2] Spaced on 5 August (early) of 16 September (late)

*** - statistically significant difference between treatments at $P < 0.001$
NS - no significant differences

Table 2 contd

Treatment	Final plant quality (0 - 5)	
	Poorly ventilated	Fan ventilated
Early spacing	1.92	2.25
1. Unt	3.17	3.08
2. Ali/Fav	3.88	3.58
3. Ali/Elv/Ali/Bra(7d)	3.42	3.38
4. Ali/Ami	4.00	4.08
5. Ami/Ami/Inv/Rip	4.25	4.29
6. Ami/Ami/Inv/Rip (7d)		
Late spacing		
1. Unt	1.81	2.02
2. Ali/Fav	2.54	2.92
3. Ali/Elv/Ali(Bra/7d)	3.75	3.58
4. Ali/Ami	3.42	3.33
5. Ami/Ami/Inv/Rip	4.08	4.17
6. Ami/Ami/Inv/Rip (7d)	4.21	4.29
Significance	NS	NS
SED (19 df)	-	-

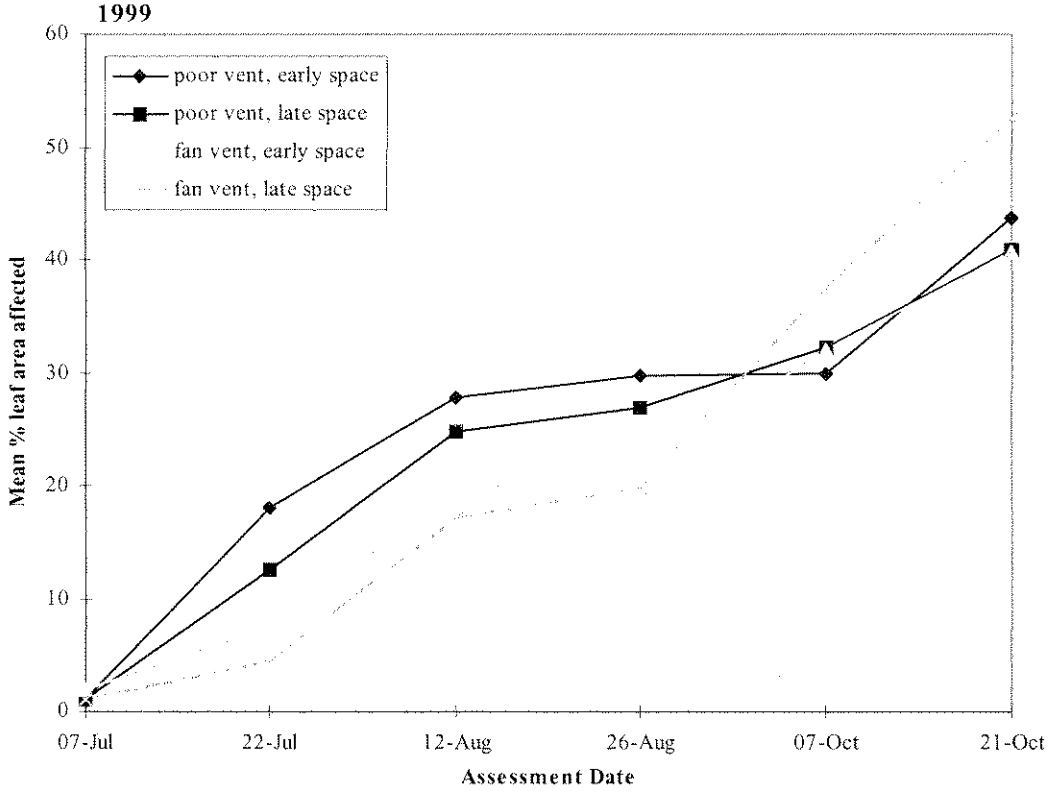
[1]All sprays applied at 14 d intervals except where indicated
[2] Spaced on 5 August (early) of 16 September (late)
NS - no significant differences

Table 3. Relative humidity (%) in two polythene tunnels, Norfolk 1999.

Measurement of %RH		Poor ventilation	Fan ventilation
Date	Time		
09 July	11:00	72	74
15 July	16:15	64	68
29 July	16:50	46	54
5 August	10:10	84	87
19 August	11:35	82	86
2 September	15:20	60	57
9 September	10:40	73	57
23 September	10:00	89	86
7 October	11:05	81	86
15 October	11:10	87	84
21 October	12:00	89	91

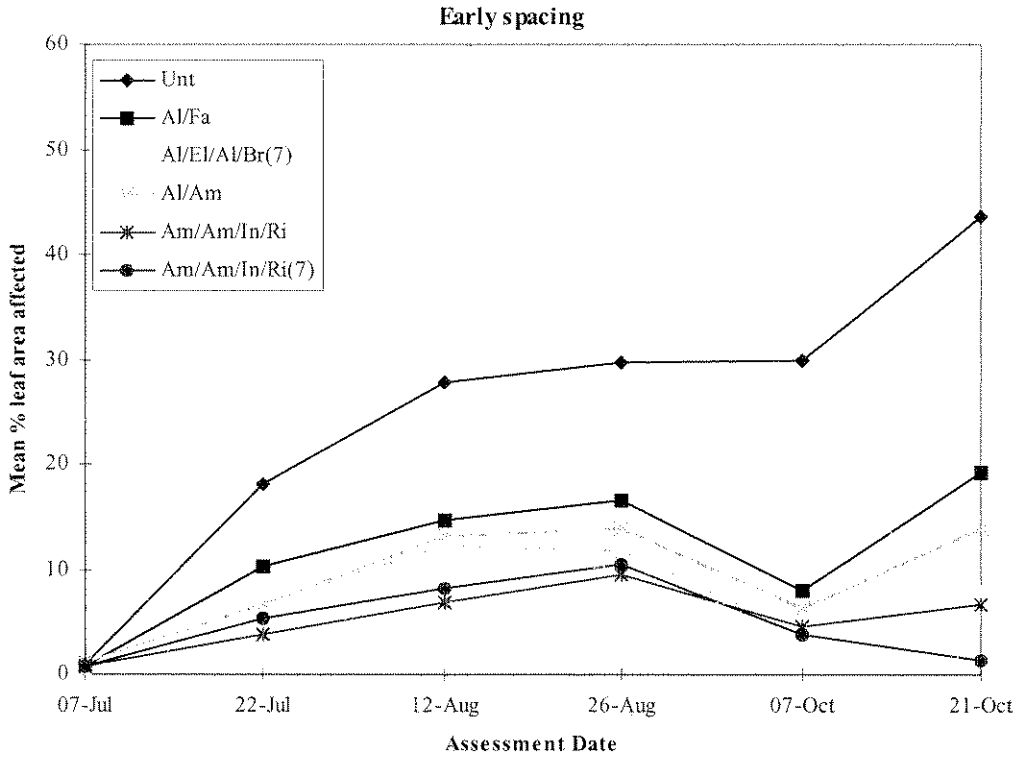
RH readings taken at foliage height from middle of respective tunnel with a whirling hygrometer.

Fig 2. Progress of Hebe downy mildew in four contrasting growing conditions - 1999



Early spacing - 5 August
Late spacing - 16 September

Fig.3 Effect of fungicide programmes on Hebe downy mildew in a poorly ventilated tunnel - 1999



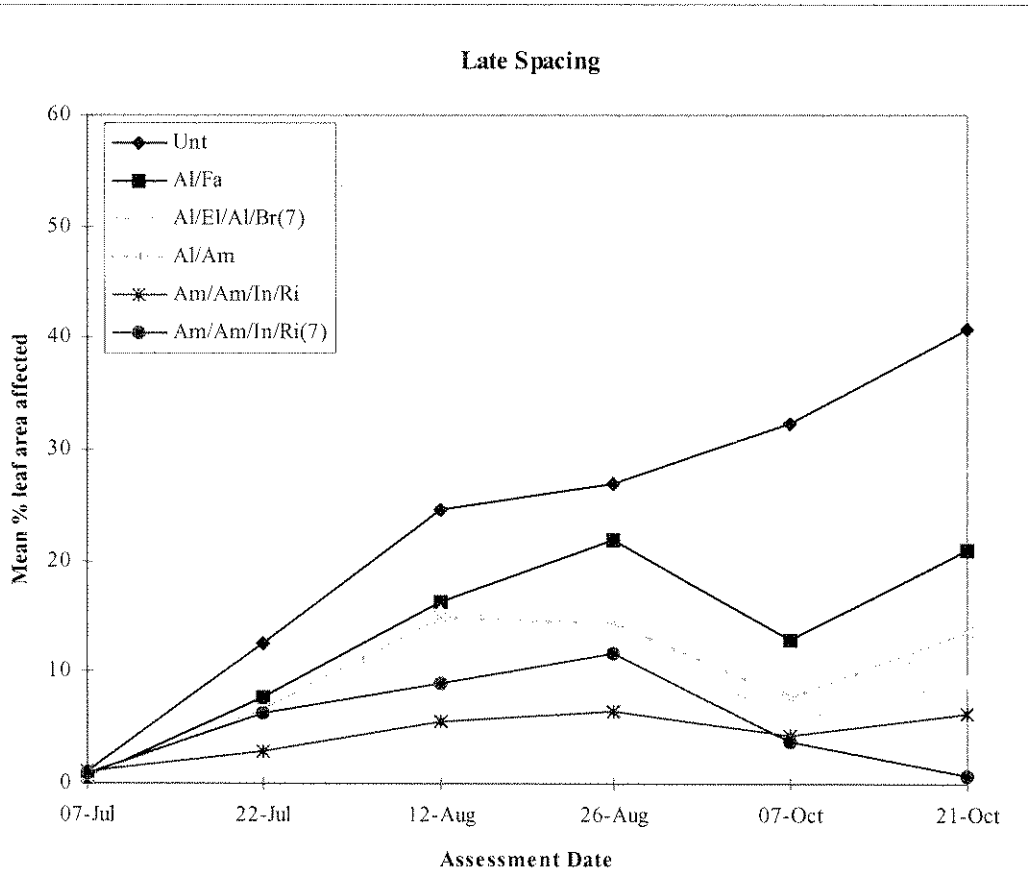
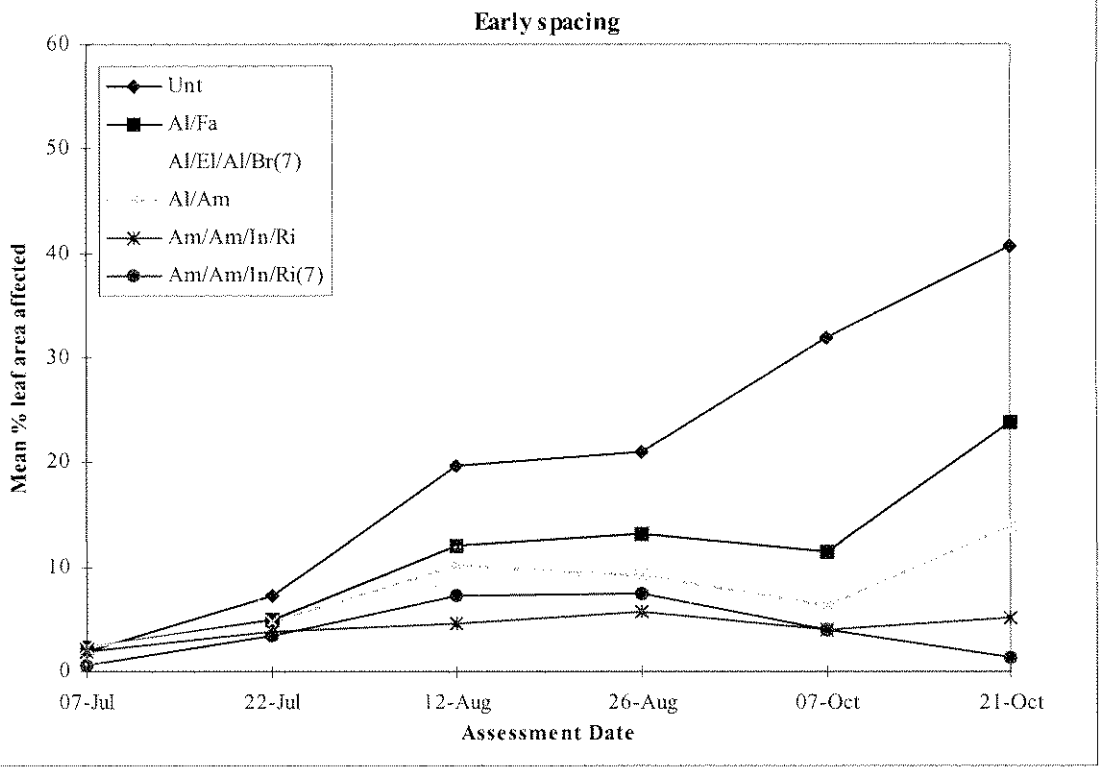
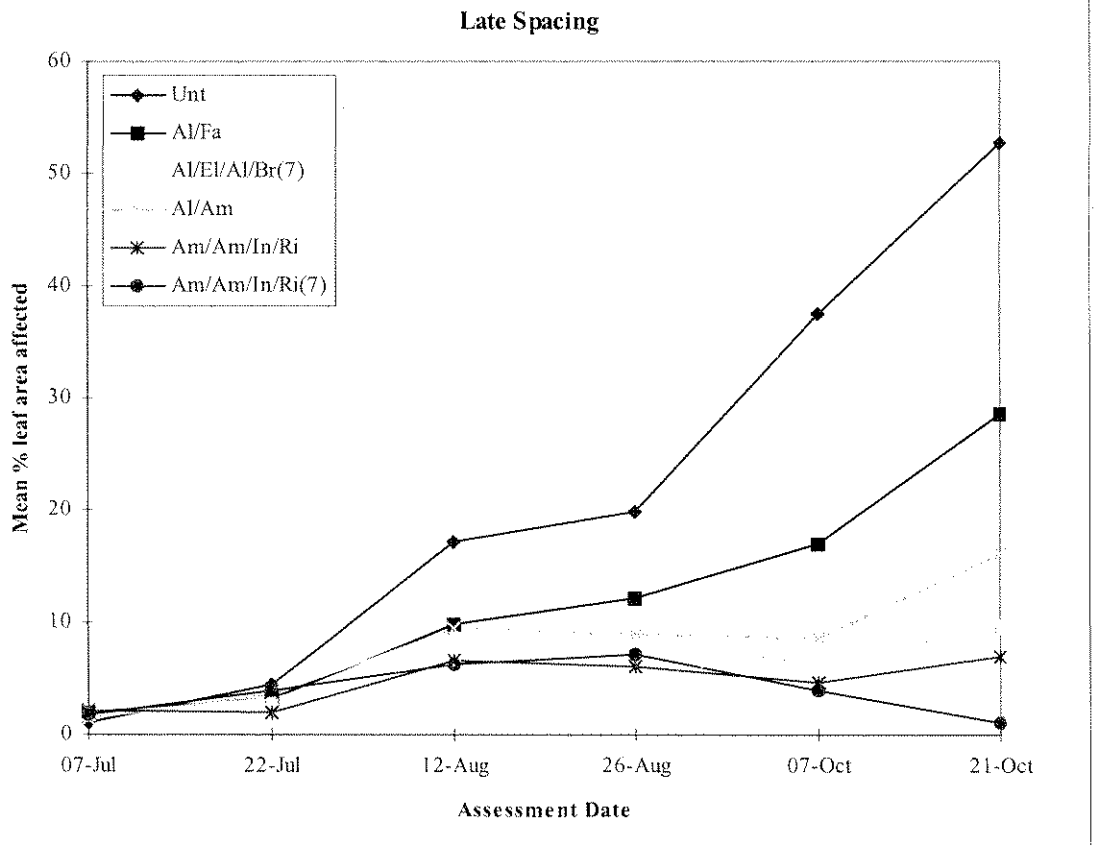


Fig 4. Effect of fungicide programmes on Hebe downy mildew in a fan ventilated tunnel - 1999





DISCUSSION

As in 1998, a severe epidemic of downy mildew developed. The small, low tunnels with overhead sprinkler irrigation probably resulted in prolonged leaf wetness after irrigation and hence favoured infection by *P. grisea.* In year 2, a marked trial edge and end effect was visible, with significantly less downy mildew on plants exposed to greater air movement. The objective this year with early plant spacing and the use of fan-assisted ventilation, was to use these cultural methods to reduce downy mildew. Both resulted in a reduction in downy mildew, though the effects were relatively small. The fan-assisted ventilation system was not as effective as hoped and no consistent reduction in humidity was measured. Alternative fan systems which are more effective at moving air close to and through the crop may prove more effective at reducing downy mildew. Increased plant spacing greater than that used in this trial is likely to have a greater effect on downy mildew, and may be warranted for stocks plants or very susceptible varieties.

Fungicide programmes 5 and 6, based on Amistar, gave excellent control of downy mildew, confirming the good results obtained last year. Programmes 3 and 4 based on Aliette, or Aliette and Amistar, were also effective. Programme 2 was less effective than other treatments, though still giving some control. Results in 1998 suggested that a metalaxyl-resistant strain of *P. grisea* may have been present at the trial site; if so, control in treatment 2 would devolve onto Aliette and the thiram component of Favour.

It is suggested that future work should investigate the relationship between leaf wetness duration and infection of Hebe by *P. grisea* more closely, to determine the basis for the observed effect of overhead irrigation, plant spacing and ventilation on disease development, with a view to providing guidelines on conditions favourable and unfavourable to development of the disease.

CONCLUSIONS

1. A severe epidemic of downy mildew developed on container grown plants of Hebe x franciscana 'Variegata', grown in low, unheated polythene tunnels with overhead irrigation.

2. Fan-assisted ventilation resulted in a slight reduction in downy mildew. Further work is needed to determine how influential air movement and leaf wetness are in determining infection risk and whether this information can be used to improve control further by cultural methods.

3. Early plant spacing slightly reduced the final severity of downy mildew compared with late plant spacing.

4. Alternation of Amistar (x2) with Invader and Ripost Pepite on a 14 day schedule, reducing to 7 days in August, was the most effective programme and resulted in the greatest plant quality score.

5. Alternation of Bravo 500 (2.2 ml/l) and Elvaron (3 g/l) with Aliette (2.5 g/l) on a 7 day schedule resulted in good disease control, as in 1998.

6. An alternating programme of Aliette (2.5 g/litre) and Favour 600SC (3 ml/litre) every 14 days gave relatively poor disease control compared with the other fungicide programmes.

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ADAS