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The results and conclusions in this report are based on a series of experiments conducted over a three-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.

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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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Grower Summary

Headline

Cost effective, very good control of powdery mildew on delphinium, gypsophila, phlox and solidago can now be achieved using preventative spray programmes and new fungicides.

Background and expected deliverables

The effective control of powdery mildew on cut flowers is essential to ensure that the harvested stems reach marketing specification. Many of the important cut flower crops are regularly affected by the disease, especially aster, cornflower, delphinium, gypsophila, phlox, scabious and solidago. Most of these crops are herbaceous multi-stem plants which inevitably form a dense canopy when grown in beds, creating the right environment (high humidity) for powdery mildew to establish, thereby creating a high disease risk.

The expected deliverables from this project are:

- Identification of novel fungicide products with activity against powdery mildew on cut flowers.
- Information on the safety of these novel fungicides on representative species of four major cut flower families (Compositae, Caryophyllaceae, Polemoniaceae and Ranunculaceae).
- A protectant spray programme giving effective control.

Summary of the project and main conclusions

Identification of effective novel fungicides

A total of 13 fungicides from nine different fungicide 'groups' were tested on solidago in year 1 of the project (2000). Four of these (Frupica, Stroby WG, Systhane 20EW and Thiovit + Agral) were found to have good activity and are commercially available (Table 1). The remainder have limited activity, or use, for a variety of reasons (Table 2).

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Table 1. Summary of fungicides identified as effective against powdery mildew and available for use on cut flowers (updated August 2003)

Product	Fungicide group and active ingredient	Permitted on		Rate	
		Protected crops	Outdoor crops	Label	Gram or ml/100 litres/1000 m²
Frupica	Anilinopyrimidines 50% mepanipyrim	✓	✓	800 g/ha	80 g
Systhane 20EW	Ergosterol biosynthesis inhibitors (EBI) 20% myclobutanil	✓		0.45 l/ha	45 ml (SOLA*)
			✓	0.225 l/ha in 750 litres	30 ml (label)
Stroby WG	Strobilurins 50% kresoxim-methyl	✓	✓	200 g/ha	20 g
Thiovit + Agral	Sulphur 80% sulphur	✓	✓	2 g/l 0.06 ml/l	200 g 6 ml

*Extrapolation from SOLA 3195/02, for use on protected raspberry

Table 2. Summary of fungicides tested and found to have limited activity or use for control of powdery mildew on cut flowers

Product	Reason not suitable or found to have limited use
Alto	Although it is as effective as Systhane on solidago powdery mildew it is only permitted on outdoor crops. Risk of leaf margin scorch (highly systemic).
Bravo 500	Not as effective as other protectant products (e.g. Thiovit).
Dorado	Although effective on mildew, use on protected crops is now illegal and use on outdoor crops must cease by 31 December 2003.
Flint	No longer marketed in the UK.
Fortress	Only permitted on outdoor crops. Found effective on solidago powdery mildew. Possibly useful in the future but requires further testing.
Fungaflor	Not as effective as some other products in the same fungicide group (e.g. Systhane 6W and Systhane 20EW).
Neon	Found to be phytotoxic on solidago (also reported to cause damage on pot plants).
Nimrod T	Only gave moderate control of solidago powdery mildew. Use must cease by 31 December 2003.

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The relative effectiveness of 13 different products on solidago powdery mildew is shown in Fig 1.

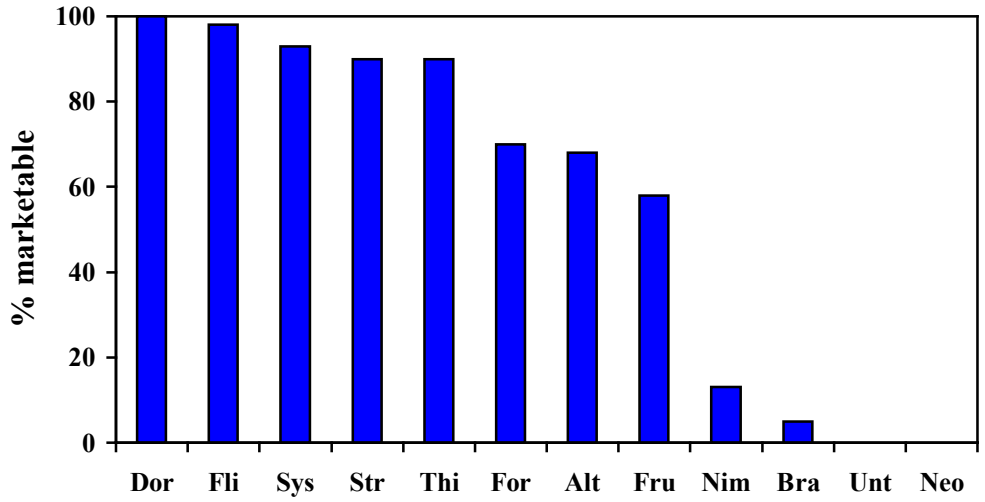

Fig 1. Effect of fungicide sprays on the % of marketable stems of solidago (year 1 of the project). The untreated plots yielded no marketable stems because mildew was widespread. Control by the fungicides varied from 100% (Dorado) down to 5% (Bravo).

Codes used for product names

Dor - Dorado
Fli – Flint
Sys – Systhane 6W or Systhane 20EW
Str - Stroby WG
Thi - Thiovit + Agral
For - Fortress
Alt - Alto
Fru - Frupica
Nim - Nimrod T
Bra - Bravo 500
Unt - Untreated control
Neo - Neon

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The effectiveness of four different products on solidago, phlox and delphinium powdery mildew is shown in Fig 2.

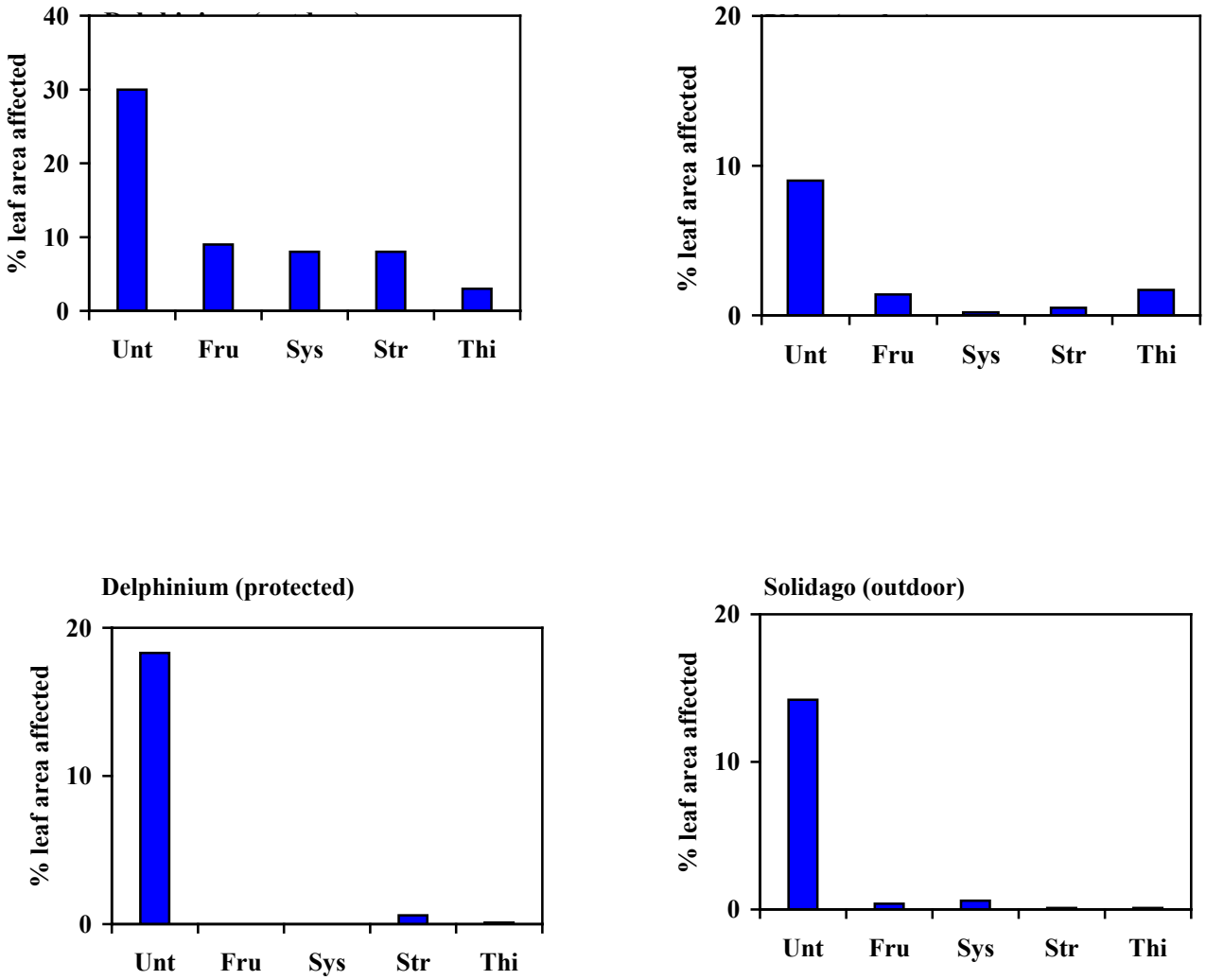

Fig 2. Comparison of the effectiveness of four fungicides against powdery mildew on delphinium (outdoor and protected), phlox (outdoor) and solidago (outdoor). Whole plot assessments are shown as % leaf area of the upper leaf surface affected by powdery mildew disease.

Codes used for product names

Unt - Untreated control
Fru - Frupica
Sys – Systhane 6W or Systhane 20EW
Str - Stroby WG
Thi - Thiovit + Agral

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Safety of novel fungicides
The five fungicides demonstrated to be effective and crop-safe on solidago (Compositae), were also found to be safe when used on gypsophila (Caryophyllaceae), phlox (Polemoniaceae) and delphinium (Ranunculaceae) at the rates listed and with up to three applications. The fungicides were tested on outdoor and protected solidago, cv. Marvellous Gold; on protected gypsophila cv. Million Stars; on outdoor phlox (white); on outdoor delphinium cv. Pacific Giant and on protected delphinium cv. Vokerfrieden.

Protectant spray programme
Protectant programmes devised and demonstrated to give good control of powdery mildew were:

- Thiovit + Agral alternating with Systhane 6W (outdoor crops of delphinium, phlox and solidago)
- Thiovit + Agral alternating with Systhane 20EW (protected crops of delphinium and solidago)

Financial benefits

Discussion with the industry and examination of MAFF Basic Horticultural Statistics (1998) indicated the total area of perennial herbaceous cut flower crops to be around 60 ha (20 ha protected; 40 ha outdoor) valued at £6.8m. Key growers have indicated that losses to powdery mildew on susceptible species average around 10 %. Assuming 50 % of the perennial herbaceous cut flower crop was susceptible to powdery mildew, and the losses on these is 10 %, the potential financial loss is estimated at £340,000 per annum. Several cases of complete crop loss to powdery mildew have occurred in recent years. We believe that the effective and crop safe treatments demonstrated here will significantly reduce or eliminate the problem.

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Large increases in the % marketable flowers can be achieved when a protectant programme is used compared with leaving plants untreated against mildew (Fig. 3). Practical information resulting from this project will also be of benefit to nursery stock growers, many of who produce the young plants for perennial cut flower production.

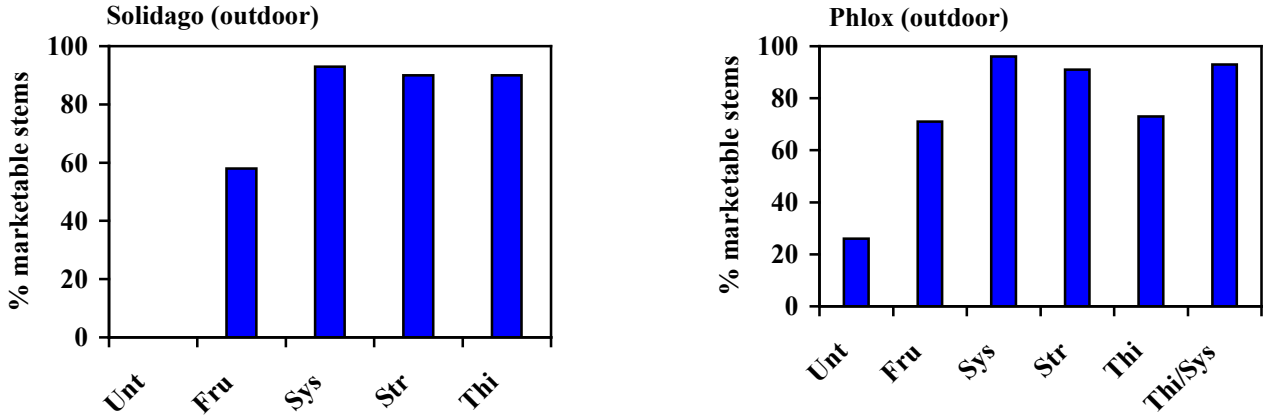

Fig. 3. Comparison of the effectiveness of four fungicides against powdery mildew on phlox (outdoor) and solidago (outdoor). The graphs show the percentage (%) marketable stems after normal removal of lower leaves at first harvest.

Codes used for product names

Unt – Untreated
Fru – Frupica
Sys – Systhane 6W (Outdoor crops)
Str – Stroby WG
Thi – Thiovit + Agral
Thi/Sys – Thiovit + Agral alternating with Systhane 6W

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Action points for growers

Powdery mildew diseases

1. Powdery mildew diseases on cut flowers often spread quickly, from lower leaves to upper parts. *It is recommended that a spray programme for powdery mildew on susceptible crops should commence as soon as new growth is visible (whether new plants or cut down) to avoid infection of the new growth.*

2. There is a propensity among powdery mildew fungi to develop resistance to fungicide. *In order to minimise the risk of selecting fungicide resistant strains, choose products from two or more different fungicide groups when devising a spray programme.*

Fungicide information

3. Five fungicides from four different groups have been demonstrated to give effective control of mildew and to be safe to use (as detailed in this report) on delphinium, gypsophila, phlox and solidago. *It is recommended that spray programmes are based on these products (Table 1).*

4. Eight fungicides are identified as having limited use for control of powdery mildew or are not suitable for use on cut flowers (Table 2). *Check this list of fungicides and if you currently use one of them, note the comment in the table and consider using an alternative from* ***Table 1***.

Spray programmes

5. A protectant spray programme of Thiovit + Agral alternating with Systhane 6W or Systhane 20EW gave very good control of powdery mildew on delphinium, phlox and solidago. *This routine spray programme is suitable where a low management input, insurance approach to disease control is required.*

6. Two further approaches to disease control were used successfully in this project: (i) Disease monitoring - two early protectant sprays, then disease monitoring (ii) First symptoms programme – no sprays until mildew is seen in the crop, then apply the recommended sequence at 7 day intervals. *Programmes based on all three approaches are available for growers to follow (Table 3).*

Delphinium crops

7. The translaminar activity (i.e. movement across the leaf) of Stroby WG was evident on delphinium, where it resulted in better control of mildew on the lower leaf surface than the other fungicides tested. *Consider using Stroby WG, or a similar fungicide with translaminar activity, on crops where mildew significantly affects the lower as well as the upper leaf surface.*

8. Fungicides differ in the amount of visible spray deposit left on a crop. The nature of the crop being treated also affects the visible residue. In these trials, Frupica left an obvious deposit on protected delphinium; *Stroby WG left virtually no deposit on delphinium and is therefore very suitable as a final treatment.*

Phlox crops

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9. Control of phlox powdery mildew was not quite as effective using Frupica compared with using Systhane 6W or Stroby WG. *Use Systhane or Stroby WG in addition to, or instead of Frupica, as the mildew-specific fungicide in a spray programme.*

10. On outdoor phlox, persistence of disease control appeared better with Systhane 6W and Stroby WG than with Frupica or Thiovit + Agral. *Use Systhane or Stroby WG as the final treatment before harvesting begins, rather than Frupica or Thiovit + Agral.*

Solidago crops

11. The protectant fungicide Thiovit + Agral gave very effective control of solidago powdery mildew. There is only a low risk of powdery mildew fungi developing resistance to this inexpensive fungicide. *Consider using Thiovit + Agral in alternation with other, more mildew-specific fungicides. Thiovit does however make stems smell of sulphur and should not be used close to marketing.*

Note (August 2003)

Systhane 6W is no longer marketed.

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Table 3. Example programmes for control of powdery mildew on delphinium, gypsophila, phlox and solidago (protected and outdoor crops)

Management approach	Spray sequence (weeks after emergence)											
	0	1	2	3	4	5	6	7	8	9	10	11
1. **Low management input** - (routine sprays every 14 days)	-	Thi	-	Sys	-	Thi	-	Sys or (Str)	-	Thi	-	Sys
2. **Disease monitoring** - (two early protectant sprays, then monitor for disease. When seen, use the sequence given)	-	Thi	-	Thi	-	-	Sys	Sys	Thi	Sys or (Str)	Thi	Sys
3. **First symptoms** - (no sprays until mildew is seen. When seen, use the sequence given)	-	-	-	-	-	-	Sys	Sys	Thi	Sys or (Str)	Thi	Sys

Thi – Thiovit+Agral; Sys - Systhane 20EW; Str – Stroby WG.
Systhane 6W is no longer marketed (August 2003).

Notes

1. **Low management input insurance programme**: apply protectant materials at approximately 14-day intervals (maximum). Reduce the spray interval to 7-10 days as the crop grows.
2. **Disease monitoring programme**: apply 2 sprays within 21 days of crop emergence, then none until first symptoms, then 2 of a mildew-specific fungicide within 7 days if the disease is seen, then alternate a protectant with a mildew specific fungicide every 7 days.
3. **First symptoms programme**: no sprays until mildew is seen, then 2 sprays of a mildew-specific fungicide within 7 days, then alternate a protectant with a mildew-specific fungicide every 7 days. *This approach requires frequent crop monitoring (e.g. weekly).*
4. Example programmes 2 and 3 assume mildew is first observed in week 6; start earlier or later according to when mildew is first seen in your crop.
5. To further reduce the risk of selecting fungicide resistant strains of mildew, consider replacing every other Systhane 20EW application with Stroby WG.
6. Aim to finish the spray programme on a mildew-specific fungicide such as Systhane 20EW or Stroby WG, rather than Thiovit so as to prolong control during flower cropping and to reduce risk of a sulphur taint on the harvested stems.

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SCIENCE SECTION

Introduction

Aster, cornflower, delphinium, gypsophila, phlox, scabious and solidago are becoming more widely grown both outdoors and under protection (heated and unheated crops) to fulfil an increasing supermarket demand for a greater variety of flowers. Unfortunately, experience has shown that all of these popular crop species are very susceptible to powdery mildew diseases. For example, crops of solidago and delphinium were badly affected each year from 1998 to 2002; gypsophila was badly affected in 1999, perennial asters in 2002, and scabious in 2001 and 2002.

The fungal species that cause powdery mildew disease include *Erysiphe cichoracearum* var. *cichoracearum* (on aster, cornflower, chrysanthemum and solidago); *Erysiphe aquilegia* (on aquilegia and larkspur); *Erysiphe knautiae* and *Sphaerotheca dipsacearum* on scabious; *Erysiphe polygoni* on delphinium; *Sphaerotheca fusca* on phlox; and a species on gypsophila (probably *Erysiphe buhrii*). *Erysiphe cichoracearum* is the most important pathogen.

The diseases mark and deform the foliage and with severe attacks, premature leaf fall results. Attacks on the upper stem and foliage generally make the stem unmarketable even with a slight infection. Another serious effect with a slight to moderate attack is a reduction in size of flower stem (both weight and stem length are reduced) and consequently the very tight supermarket specifications may not be so easily met. For example, where the stem length is present but stems are thinner due to powdery mildew, the product will be downgraded.

Powdery mildew diseases tend to be most troublesome in the late summer and early autumn. Most of these crops are herbaceous multi-stem plants which inevitably form a dense canopy when grown in beds, creating the right environment (high humidity) for powdery mildew disease to establish, thereby increasing disease risk. Because of the dense growth, fungicides need to be applied as the crop is developing, to maintain cover on the new growth.

Currently growers generally apply sprays only when powdery mildew is seen and this often proves to be only partially effective, or completely ineffective. Some growers have tried protectant sprays but with limited success.

The **commercial objective** of this project is to develop effective and crop safe fungicide treatment for representative species of the four major cut flower families susceptible to powdery mildew (Compositae, Caryophyllaceae, Polemoniaceae, Ranunculaceae).

In the first project year, experiments were conducted to evaluate a range of current and novel fungicides as individual treatments for their effectiveness in controlling powdery mildew on field and protected crops of solidago. In the second year, three approaches to the management of powdery mildew on solidago were devised and tested using seven fungicides. In this third year, the crop-safety and efficacy of four key fungicide products and one preventative programme, devised and tested in years 1 and 2 on solidago, were tested on delphinium, gypsophila and phlox.

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MATERIALS AND METHODS

Site and crop details

Four trials were undertaken on a commercial nursery at Spalding, Lincolnshire, using varieties known to be susceptible to powdery mildew. The trials were on:

1) Outdoor delphinium, cv Pacific Giant
2) Outdoor phlox (white)
3) Protected delphinium, cv Volkerfrieden
4) Protected gypsophila, cv Million Stars

Plants were grown in 4-row beds at 35 x 35-38 cm spacing, except for the gypsophila, which was grown in 2-row beds at 33 x 33 cm spacing. The two trials on delphinium were both conducted on the second-cut crop.

Treatments

1. Untreated control
2. Frupica (50% mepanipyrim)
3. Systhane 20EW (protected crops) (20% myclobutanil)
   Systhane 6W (outdoor crops) (6% myclobutanil)
4. Stroby WG (50% kresoxim – methyl)
5. Thiovit (80% sulphur) + Agral (non-ionic wetter)
6. A preventative programme of Thiovit+Agral alternating with Systhane 20EW (protected crops) and Systhane 6W (outdoor crops).

The primary objective of the trials was to establish the crop safety of the selected treatments by applying fungicides three times at 14-day intervals from shortly after emergence of plant growth. Fungicide treatment was then to be stopped. However, if mildew occurred on untreated plants, the programmes would be restarted, applying two sprays at 7-day intervals.

The purpose of this second set of fungicide applications was to determine the relative effectiveness of the different fungicides at controlling established mildew. Treatment 6 was a routine preventative programme, where fungicides were applied preventatively every 14 days until mildew occurred in the crop, and the spray interval was then reduced to 7 days.

In practice, the number of sprays applied in some trials was less than planned due to early appearance of mildew. Also, for the two outdoor trials, wet weather prevented spray application on some of the intended dates. The exact spray dates and spray intervals are shown in the crop diaries.

The rates of fungicides used were:

Frupica at 800 g/ha

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Thiovit + Agral at 2 g/litre + 0.06 ml/litre
Stroby WG at 0.2 kg/ha
Systhane 20EW at 0.45 l/ha
Systhane 6W at 1 g/l.

Sprays were applied at 500 litres/ha (50 ml/m²). For further information on the choice of products please see Appendix 1.

Experiment design and analysis
Each trial comprised a randomised block design with four replicate blocks. There was double replication of the untreated control. Plot size for the outdoor trials was 1.7 m lengths of 1.2 m wide bed (2.04 m²). Plot size for the glasshouse trial of gypsophila was 1.1 m lengths of 1.2 m wide bed (1.32 m²); that of delphinium was 2.5 m lengths of 1.2 m wide of bed (3.0 m²). Results were examined by ANOVA, or another appropriate statistical test where initial examination of data showed that they were not suitable for ANOVA.

Assessments

During growth
1. Estimated % leaf area affected by powdery mildew (average of 4 positions in each plot).
2. Records were made of any leaf scorch, yellowing or stunting.

At harvest
For the glasshouse delphinium and outdoor phlox, all marketable stems in the central area of each plot were harvested and assessed. For the outdoor delphinium, 10 stems at the normal marketing stage (the lowest flowers on the stem just opening), or just past this stage, were cut and the following assessments made:

1. % leaf area affected by powdery mildew (prior to any normal leaf removal). For delphinium, where mildew caused obvious browning to the lower leaf surface, the upper and lower leaves were assessed separately.
2. Number of stems unaffected by powdery mildew after the normal removal of leaves from the stem. These were classed as marketable.
3. Spray deposit was assessed according to estimated % leaf cover (0-100) and intensity of deposit (slight – 1, moderate – 2, obvious – 3).

No mildew occurred on the gypsophila therefore no disease assessments were possible.

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Crop diaries

	Delphinium (outdoor)	Phlox (outdoor)	Delphinium (glasshouse)	Gypsophila (glasshouse)
Crop planted	November 2001	June 2002	August 2002	August 2002
Crop cut down	March 2002	-	-	-
Spray 1	4 July	19 June	30 August	16 August
2	17 July	4 July	12 September	30 August
3	2 August	17 July	20 September	12 September
4	16 August	2 August	-	27 September
5	-	16 August	-	10 October
6	-	23 August	-	-
Interim assessments 1	9 August	15 August	-	-
2	15 August	22 August	-	-
Harvest 1	23 August	5 September	27 September	-
2	-	12 September	10 October	-
Mildew first confirmed	2 August	15 August	17 September	Not found

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RESULTS AND DISCUSSION

Outdoor delphinium

None of the fungicide treatments resulted in leaf scorch, stunted growth, obvious spray deposit, or had any noticeable adverse effect on crop development.

Powdery mildew was first observed in the crop on 2 August when the crop was close to harvest. However, in order to test the effectiveness of the fungicides in controlling disease, harvesting was delayed past the normal marketing stage. It was planned to apply 2 sprays at 7 days apart as soon as the disease was seen. Unfortunately, a wet spell then occurred and only one further spray was possible (16 August) before the crop was finally harvested (23 August).

In addition to the obvious white mildew on upper leaf surfaces, there was considerable browning on the lower surfaces associated with mildew, and infection of the stems leading to browning and twisting. At the interim disease assessment on 9 August, no significant differences were found. However, on 15 August, all treatments significantly reduced mildew severity on the leaves, but treatments were not so effective on the stems, except for Stroby WG. This was probably because of the dense nature of the mature crop preventing good spray coverage in the centre of beds (Table 1).

Table 1. Effect of fungicide programmes on development of powdery mildew on upper leaf surface and stems of outdoor delphinium (Pacific Giant) - August 2002 (interim whole plot assessments)

Treatment	% leaf area affected		% stems affected
	9 Aug	15 Aug	15 Aug
1. Untreated	5.0	30	40.4
2. Frupica	2.4	9	14.2
3. Systhane 6W	3.2	8	16.7
4. Stroby WG	5.8	8	9.7
5. Thiovit+Agral	1.7	3	18.8
6. Thiovit+Agral/Systhane 6W	1.3	3	10.0
Significance (19 df)	0.676	<0.001	<0.001
SED between trts	3.51	4.70	7.69
vs control	3.04 (skewed)	4.08	6.66

Sprays applied: 4 July, 17 July, 2 August and 16 August.

A Friedman's test on the 9 August data indicated no significant differences (P= 0.391, df=6) between treatments.

At the harvest assessment, one week after the final spray, four of the treatments (Frupica, Stroby WG, Thiovit+Agral and Thiovit+Agral/Systhane 6W) were very

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effective, reducing disease severity on the upper leaf surface to between just 1 and 3%. The untreated level at this time was 25% leaf area affected (Table 2). Systhane 6W was less effective. Treatments were less effective at controlling mildew on the lower leaf surface although Stroby WG was considerably better than other treatments. Stroby WG is known to have translaminar activity (i.e. the fungicide moves from the upper to the lower surface).

Stroby WG was also very effective at reducing the % of stems with obvious mildew on the stem, to 4.9% affected, compared with the untreated at 28.9%. This difference was statistically significant. The protectant programme was the next best treatment at 9.6%.

Table 2. Effect of fungicide programmes on powdery mildew on outdoor delphinium at harvest-23 August 2002

Treatment	% leaf area affected		% stems affected
	Upper leaf surface	Lower leaf surface	
1. Untreated	25	34	28.9
2. Frupica	1	20	12.7
3. Systhane 6W	13	26	11.2
4. Stroby	3	10	4.9
5. Thiovit+Agral	3	33	16.5
6. Thiovit+Agral/Systhane 6W	2	21	9.6
Significance (19 df)	<0.001	0.03	0.012
SED between trts	4.19	7.44	7.29
vs control	3.63	6.44	6.31 (skewed)

10 stems from the central area of each plot were assessed.
A Friedman's test on the incidence of affected stems showed significant differences between treatments (P=0.046, df=6)

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Outdoor phlox

As with outdoor delphinium, none of the fungicide treatments caused any visible crop damage or left an obvious deposit.

Powdery mildew started on the lower leaves and spread up the plants to affect mid and upper canopy leaves. It was first confirmed in the trial on 15 August, at which stage 5.8% leaf area of untreated plants was affected, with 1-2 % on most other treatments, and nil on the plants treated regularly with the Thiovit+Agral/Systhane 6W preventative programme (Table 3). One week later, leaf area affected had increased to 9% on untreated plants, whilst all the treated plants had less than 2% infection and again the Thiovit+Agral/Systhane 6W preventative programme was still mildew free.

Table 3. Effect of fungicide programmes on powdery mildew on outdoor phlox (white) – August 2002 – interim assessments (15 and 22 August).

Treatment	% leaf area affected	
	15 August	22 August
1. Untreated	5.8	9.1
2. Frupica	0.9	1.4
3. Systhane 6W	0.3	0.2
4. Stroby	0.3	0.5
5. Thiovit+Agral	1.3	1.7
6. Thiovit+Agral/Systhane 6W	0.0	0.0
Significance (19 df)	0.389	0.421
SED between trts	3.86	6.20
vs control	3.34 (skewed)	5.37 (skewed)

Sprays applied: 19 June, 4 July, 17 July, 2 August, 16 August, 23 August.

Friedman's tests indicated differences were statistically significant at the 5% level on 15 August (P=0.016, df=6); not on 22 August (P=0.076)

Flowers were harvested as they became ready on 5 and 12 September, at 2 and 3 weeks after the final spray. They were assessed after removal of lower leaves in accordance with usual practice;. The level of mildew on treated plants was very low at less than 1% whereas the untreated control was much greater at 2.4% (5 September). By 12 September, this had risen to nearly 4%, whereas all treatments were still close to zero (Table 4).

The % marketable stems was over 90% with three treatments, Systhane 6W being the best at 96% (5 September) and 100% (12 September), compared with the untreated at 26% (5 September) and 31% (12 September). The Thiovit+Agral/Systhane 6W preventative programme was marginally better than Stroby WG, and both were considerably better than Frupica and Thiovit+Agral.

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After the central area of each plot had been harvested, the outer plants were left in the bed. An assessment of these guard plants on 10 October, 7 weeks after the final spray application, indicated a greater persistence of control with Systhane 20EW, Stroby WG and Thiovit+Agral/Systhane 6W than with Frupica or Thiovit+Agral (Table 5).

Table 4. Effects of fungicide programmes on powdery mildew on outdoor phlox at harvest – September 2002

Treatment	No of Sprays	% leaf area affected		% stems marketable	
		5 Sep	12 Sep	5 Sep	12 Sep
1. Untreated	0	2.43	3.89	25.9	30.6
2. Frupica	5	0.38	0.41	71.0	64.2
3. Systhane 6W	5	0.02	0.00	96.2	100.0
4. Stroby WG	5	0.07	0.03	91.2	92.7
5. Thiovit+Agral	5	0.57	0.76	73.2	70.7
6.Thiovit+Agral/Systhane	3+3	0.07	0.03	93.2	96.5
Significance (19 df)		0.285	0.273	<0.001	<0.001
SED between trts		1.46	2.37	14.44	17.17
vs control		1.26 (skewed)	2.05 (skewed)	12.50	14.87

Friedman's test indicated the % leaf area affected data had significant differences between treatments on 5 September (P=0.007) and 12 September (P=0.006).

Table 5. Relative persistence of mildew control with different fungicides on outdoor phlox, 7 weeks after the final spray

Treatment	% leaf area affected (10 October)
1. Untreated	42.6
2. Frupica	20.1
3. Systhane 6W	8.7
4. Stroby WG	4.5
5. Thiovit+Agral	15.3
6. Thiovit+Agral/Systhane 6W	6.8
Significance (19 df)	0.007
SED between trts	11.87
vs control	10.28 (skewed)
Friedman's test (6 df)	0.033

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Glasshouse delphinium

Although none of the fungicide treatments caused crop damage, a spray deposit was visible on the trial crop after treatment with Systhane 6W. This did not affect marketability, but spray deposit by all treatments was assessed for reference.

Powdery mildew was noted in the trial crop on 17 September, 5 days after application of the second spray. The disease was still at a low level on 20 September. At harvest on 27 September, 1 week after the final spray, there was moderately severe attack on untreated plants and all fungicides were giving excellent control of the disease (Table 6). A Friedman's test on the data of 27 September indicated significant differences between treatment (P=0.002).

Table 6. Effect of fungicide programme on powdery mildew on glasshouse delphinium

Treatment	No. of sprays	% leaf area affected (27 September)
1. Untreated	0	18.3
2. Frupica	3	0.0
3. Systhane 20EW	3	0.0
4. Stroby WG	3	0.6
5. Thiovit+Agral	3	0.1
6.Thiovit+Agral/Systhane	3	0.4
Significance (19 df)		0.075
SED between trts		8.79
vs control		7.62 (skewed)

Sprays applied: 30 August, 12 September, 20 September

Treatments differed significantly in the amount of visible spray deposit on plants (Table 7). Deposit was greatest with Frupica and Systhane 20EW and least with Stroby WG and Thiovit + Agral.

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Table 7. Fungicide spray deposit on protected delphinium after three applications – 27 September 2002

Treatment	Extent of spray Deposit on leaves (% cover)	Intensity of deposit(0-3)
1. Untreated	0.0	0.0
2. Frupica	66.4	1.4
3. Systhane 20EW	45.8	1.0
4. Stroby WG	0.1	1.0
5. Thiovit+Agral	7.6	0.4
6.Thiovit+Agral/Systhane	21.6	0.7
Significance (19 df)	<0.001	<0.001
SED between treatments	6.43	0.14
vs control	5.56	0.12

Glasshouse gypsophila

No powdery mildew occurred in this trial. No adverse effect on plant growth was observed following any of the fungicide treatments.

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CONCLUSIONS

Fungicide information

1. Five fungicides (Frupica, Systhane 6W (outdoor crops) or Systhane 20EW (protected crops), Stroby, Thiovit + Agral) and one protectant programme (Thiovit + Agral alternating with Systhane 6W or Systhane 20EW) were found to cause no damage to outdoor delphinium cv. Pacific Giant, protected gypsophila cv. Million Stars or outdoor phlox (white) when used at the rates given in this report.

2. The novel fungicides when used as protectant sprays, and the protectant programme, gave good control of powdery mildew on delphinium and phlox. No mildew occurred on the gypsophila so no conclusions can be drawn here.

Delphinium trials

3. The translaminar activity of the strobilurin fungicide Stroby WG was clearly demonstrated on the outdoor delphinium trial where it resulted in much better control of mildew on the lower leaf surface (and on stems) than other treatments.

4. On protected delphinium cv. Volkerfrieden, no differences between the individual fungicide treatments were evident.

5. Fungicide spray deposit was most noticeable on protected delphinium. After three sprays, spray deposit was particularly noticeable with Frupica and Systhane 6W. Stroby WG left virtually no visible deposit and that from Thiovit + Agral was very slight.

Phlox trial

6. On outdoor phlox, five sprays of Systhane 6W and Stroby WG appeared to give better control of mildew than Frupica and Thiovit + Agral.

7. On outdoor phlox, observations on unharvested plants 48 days after the final spray application indicated good persistence of disease control with Systhane 6W, Stroby WG and the alternating Thiovit+Agral/Systhane programme. Persistence of control was considerably less good with Frupica and Thiovit + Agral.

Spray programmes

8. The protectant programme of Thiovit + Agral alternating with Systhane 6W or Systhane 20EW gave control of mildew equal to that of the best individual fungicide in all trials.

9. A fungicide spray programme which is crop–safe, effective and at low risk of selecting resistant strains of mildew has been validated on solidago, delphinium and phlox. Several similar programmes could be devised based on the results of this project.

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TECHNOLOGY TRANSFER

1. Presentation by Tim O'Neill at the HRI/HDC Cut flowers Growers meeting, HRI Kirton, 26 September 2002.
2. Presentation by Tim O'Neill at HRI/HDC Cut Flower Conference, HRI Wellesbourne, 27 November 2001, within a general talk on cut flower diseases: Know your enemy – the key to good disease control.
3. Lecture by Tim O`Neill at BSPP Powdery Mildews meeting, Imperial College, London, 6 April 2001. Biology and control of powdery mildew diseases on cut flowers.
4. Presentation by Tim O'Neill at HRI/HDC Cut flowers Growers Meeting, HRI Kirton, April 2000
5. Cut flower mildew control programmes. *HDC News* **71**, 8 (News reports).

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APPENDIX 1

Comments on selection of fungicide treatments (February 2002).

1. The four fungicides chosen as treatments 2 to 5 (Frupica, Systhane, Stroby WG and Thiovit) come from four different fungicide groups (anilinopyrimidine, DMI, strobilurin and sulphur respectively) providing a useful selection of materials to alternate in anti-resistance strategies.
2. All four products showed good activity against solidago powdery mildew *(Erysiphe cichoracearum,* delphinium powdery mildew *(E. polygoni)* and phlox powdery mildew (*Sphaerotheca fusca).*
3. Dorado was not included because it is no longer permitted on protected crops, nor or outdoor crops after 31 December 2003. Systhane 6W/20EW is in the same fungicide group and a good alternative, with formulations available for use under protection and outdoors.

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