

Project number: BOF 44

Title: Protected and outdoor cut flowers: development of effective and crop-safe fungicide treatments for control of powdery mildew.

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

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

Commercial benefits of the project

Growers can obtain reliable control of powdery mildew on solidago by using the fungicide programmes devised, tested and found effective in this project.

Objectives and background

Powdery mildew diseases can seriously affect production of commercially important cut flower crops. Currently, these disease are causing increasing problems. Even slight disfigurement arising from powdery mildew infection can lead to flowers failing a supermarket specification. Cost effective and crop-safe fungicide treatments to prevent disease are urgently required. The objectives of this project are to: (i) determine the effectiveness of comprehensive protectant treatments, (ii) investigate the effectiveness of current and some novel fungicides applied at different timings, (iii) test the crop safety of fungicides found to be effective on the major crop species and cultivars, both protected and outdoor production.

Work completed in previous years (2000)

Trial on outdoor solidago - Summer 2000

Eleven fungicides were evaluated for their effectiveness in controlling powdery mildew (*Erysiphe cichoracearum*) in a field crop of solidago cv. Marvellous Gold in Spalding, Lincs. Natural infection occurred 5 weeks after the trial was established and increased to affect 14 % leaf area on untreated plants by harvest; no stems in untreated plots were marketable. All of the fungicide treatments reduced powdery mildew and increased the number of marketable stems. Eight treatments resulted in less than 1 % mildew at harvest (Alto, Dorado, Frupica, Flint, Fortress, Stroby, Systhane 6W, Thiovit + Agral) and no crop damage. Neon damaged plants, causing an obvious brown leaf spot, and it is not suitable for use on the crop. Alto appeared to result in a slight reduction in stem length (by 2 cm), and Stroby appeared to bring forward flowering. Dorado resulted in the greatest number of marketable stems. Thiovit plus Agral was slightly more effective than Bravo in preventing powdery mildew. Alto, Flint and Stroby appeared to have the best systemic activity and plants treated with these fungicides had least mildew on upper leaves and stems 13 days after the final spray. Stem weight was not significantly affected by fungicide treatment.

Trial on protected solidago - Autumn 2000

Eleven fungicides were evaluated for control of powdery mildew on the second crop of a planting of cv. Tara in a glasshouse in Spalding. The first sprays were applied on 3 August. Fungicides tested were identical to the outdoor trial except for the addition of Fungaflor (label recommendation for protected crops only) omission of Alto (treatment permitted on outdoor crops only) and replacement of Systhane 6W (outdoor crops only) with Systhane 20EW (protected crops only) to comply with pesticide label conditions of approval. Natural infection was observed on 30 August,

in one untreated plot, but failed to develop and no results were obtained on fungicide efficacy. None of the treatments have any obvious adverse effects on plant growth.

Specific targets for 2001

1. To devise and evaluate fungicide programmes for their effectiveness in controlling powdery mildew (*Erysiphe cichoracearum*) on solidago, both outdoors and in a glasshouse.
2. To record any adverse effect of the fungicide programmes on crop growth.
3. To determine the effect of treatments on marketable yield of flower stems.

Summary of results and conclusions

Trial on outdoor solidago, Summer 2001

Three approaches to the management of powdery mildew on solidago were devised and subsequently tested:

1. Low management input insurance - routine sprays.
2. Disease monitoring - two early protectant sprays then disease monitoring.
3. First symptoms - no sprays until mildew was observed in the crop.

Five fungicides chosen from the results of the 2000 trials (Dorado, Systhane 6W, Thiovit, Twist and Frupica) were used in the above programmes giving nine fungicide combinations. These treatments were evaluated on a crop of solidago cv. Marvellous Gold, on a commercial nursery between May and July. No powdery mildew occurred in the crop so it was not possible to determine their effectiveness. None of the fungicides caused crop damage.

Trial on protected solidago, Autumn 2001

The same three approaches to management of mildew were tested on the second crop of a planting of cv. Marvellous Gold in a glasshouse in Spalding between July and October. The programmes tested were:

1. Low management input insurance - routine sprays:
 - Systhane 20EW and Thiovit
 - Frupica and Thiovit
 - Fungaflor and Thiovit
 - Thiovit at 14 day intervals
 - Thiovit at 28 day intervals
2. Disease monitoring - two early protectant sprays then disease monitoring:
 - Thiovit, Systhane 20EW, Thiovit, Systhane 20EW
 - Thiovit, Frupica, Thiovit, Frupica
3. First symptoms - no sprays until mildew was observed:
 - Systhane 20EW, Thiovit, Systhane 20EW
 - Frupica, Thiovit, Frupica

The number of sprays applied over the 10-week production period ranged from three to nine. Natural infection was observed at trace levels on 17 August when plants were around 10-15 cm tall, and became obvious in untreated plots by 28 August although it remained at a relatively low level through to harvest.

At the final assessment there were around 50 mildew spots on untreated stems (1.1% leaf area affected) and only trace levels (less than 1 spot per stem and less than 0.05% leaf area affected) on all of the treated stems, except for treatment 10 (Thiovit at 28 day intervals) where there was a higher disease level, probably due to the long interval since the last spray.

The mean number of marketable stems was 90-100% for all treatments except the untreated (0%), Thiovit at 28-day intervals (60%) and the Thiovit/Fungaflor programme (80%). Treatments had no significant effect on stem length or weight.

There was a slight deposit visible following treatment, being most noticeable where Frupica was the final spray.

The persistence of control from Systhane 20EW and Frupica as a final spray was greater than that of Fungaflor.

Details of fungicides, which are permitted on solidago, active against powdery mildew and safe to the crop, are summarised in Table 1.

Action points for growers

1. Powdery mildew on solidago often spreads quickly from lower leaves to affect the upper parts. *It is recommended that a spray programme for mildew should commence soon after planting, before leaves become affected.*
2. Eleven fungicides from seven different groups have been demonstrated to give significant control of solidago powdery mildew. *Details are given in Table 1.*
3. There is a tendency among powdery mildew fungi to develop resistance to fungicides. *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 (see Table 1).*
4. Three approaches to disease management were devised and tested: (1) low management input insurance programme = routine sprays; (2) disease monitoring programme = two early sprays then disease monitoring; (3) first symptoms programme = no sprays until mildew is seen in the crop. All three approaches were successful using the treatments selected. *Programmes based on these approaches are available for growers to follow (Table 2).*
5. The protectant fungicide Thiovit + Agral gave very effective control. There is only a low risk of powdery mildew developing resistance to this inexpensive multi-site inhibitor. *Consider using Thiovit in alternation with other, more mildew-specific, fungicides. Thiovit does, however make stems smell of sulphur. Be wary of using this fungicide close to marketing.*
6. *Dorado gave very good control of powdery mildew and all stems were marketable. Consider using Dorado in spray programmes.* Currently this product has a label recommendation for control of mildew on both protected and outdoor ornamental crops, valid until 31 July 2002. However, since this project started, the manufacturers have not supported continued approval of Dorado on ornamentals, except roses (Pesticide Monitor, August/September 2000). *After 31 July 2002, Dorado can only be used on outdoor crops. Systhane 20EW is a suitable alternative to use on protected crops.*
7. Neon was phytotoxic to solidago 'Marvellous Gold', even when tested at half rate. *It is recommended that neither this product nor other fungicides based on spiroxamine should be used on solidago or other cut flower crops.*
8. In year 1, the cost of fungicide for treating 1,000 m² with a programme of five sprays ranged from just 14p (Thiovit + Agral) to £5.71 (Nimrod T) according to product. *So it is very cost-effective to control mildew on solidago.*
9. In year 2, Fungaflor when used as the final spray of a sequence, gave less persistent control than Systhane 20EW or Frupica. *Aim to use Systhane 20EW or Frupica as a final spray close to harvesting on protected crops, and Dorado or Systhane 6W on outdoor crops.*

Table 1. Summary of fungicides permitted on solidago, active against powdery mildew and safe to the crop - (based on results of trials conducted in HDC project BOF 44)

Fungicide group Fungicide = product name (active ingredient)	Permitted on:		Rate used	Comments
	Protected crops	Outdoor crops		
<i>Anilinopyrimidine</i>				
Frupica (50% mepanipyrim)	<input type="checkbox"/>	<input type="checkbox"/>	800 g/ha	Listed as Kif 3535 - an experimental material, in year 1 report
<i>Ergosterol biosynthesis inhibitor (EBI)</i>				
Dorado (20% pyrifenoX)	<input type="checkbox"/> *	<input type="checkbox"/>	0.25 ml/l	*Not permitted on protected crops after 31 July 2002
Fungaflor (20% imazalil)	<input type="checkbox"/>	X	0.5 ml/l	
Systhane 6W (6% myclobutanil)	X	<input type="checkbox"/>	1 g/l	
Systhane 20EW (20% myclobutanil)	<input type="checkbox"/>	X	0.45 l/ha	
<i>Strobilurins</i>				
Stroby WG (50% kresoxim-methyl)	<input type="checkbox"/>	<input type="checkbox"/>	200 g/ha	New label approval for use on protected ornamentals
Twist (15% trifloxystrobin)	X	<input type="checkbox"/>	2 l/ha	35 day harvest interval
<i>Quinoline</i>				
Fortress (quinoxifen)	X	<input type="checkbox"/>	150 ml/ha	
<i>Sulphur</i>				
Thiovit (80% sulphur)	<input type="checkbox"/>	<input type="checkbox"/>	2 g/l	Used with Agral (0.06 ml/l)
<i>Phthalonitrile</i>				
Bravo 500 (50% chlorothalonil)	<input type="checkbox"/>	<input type="checkbox"/>	2.2 ml/l	Equivalent chlorothalonil products are available
<i>Hydroxyprimidine + EBI</i>				
Nimrod T (bupirimate + triforine)	<input type="checkbox"/>	X	3.2 ml/l	

Products with the same mode of action are grouped together in the same "fungicide group". If mildew becomes resistant to one fungicide in a group, it is likely to be resistant to all products in the same group.

Note

Use of the above fungicides on outdoor and protected crops of solidago may be permitted either via on-label approvals or off-label under the Revised Long Term Arrangements for Extension of Use (2000). Although approved, off-label uses are not endorsed by the product manufacturer and such treatments are made entirely at the risk of the user.

Regular changes occur in the approved status of pesticides arising from changes in pesticide legislation or for other reasons. For the most up to date information, please check with a professional supplier or with the Pesticides Safety Directorate (PSD). Tel: (01904) 462 500, or use the website www.pesticides.gov.uk or email: p.s.d.information@psd.defra.gsi.gov.uk

Always read the product labels before applying pesticides. Use pesticides safely.

Table 2. Example programmes for control of solidago powdery mildew

Management approach	Spray sequence (weeks after emergence)												
	0	1	2	3	4	5	6	7	8	9	10	11	
<u>Outdoor crop</u>													
1. Low management input insurance programme	-	Thi	-	Dor	-	Thi	-	Dor or (Str)	-	Thi	-	Dor	
2. Disease monitoring programme	-	Thi	-	Thi	-	-	Dor	Dor	Thi	Dor or (Str)	Thi	Dor	
3. First symptoms programme	-	-	-	-	-	-	Dor	Dor	Thi	Dor or (Str)	Thi	Dor	
<u>Protected crops</u>													
1. Low management input insurance programme	-	Thi	-	Sys	-	Thi	-	Sys (Str)	-	Thi	-	Sys	
2. Disease monitoring programme	-	Thi	-	Thi	-	-	Sys	Sys	Thi	Sys or (Str)	Thi	Sys	
3. First symptoms programme	-	-	-	-	-	-	Sys	Sys	Thi	Sys or (Str)	Thi	Sys	

Thi - Thiovit; Sys - Systhane 20EW (protected crops) or Systhane 6W (outdoor crops); Dor - Dorado; Str – Stroby WG

Notes

- 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.
- 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.
- 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).*

- 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.
- To further reduce the risk of selecting fungicide resistant strains of mildew, consider replacing every other Systhane 20EW application with Stroby WG (protected crops); and consider replacing every other Dorado application with Stroby WG or Twist (outdoor crops).
- Aim to finish the spray programme on a mildew-specific fungicide such as Systhane 20 EW, Dorado 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.

Anticipated practical and financial benefits

Discussion with the industry and examination of MAFF Basic Horticultural Statistics (1998) indicate the total area of perennial herbaceous cut flower crops is 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 is 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. Practical information resulting from this project will also be of benefit to nursery stock growers, many of whom produce the young plants for perennial cut flower production.

SCIENCE SECTION

INTRODUCTION

Aster, cornflower, delphinium, gypsophila, scabious, solidago, and phlox 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 in both 1998 and 1999; gypsophila was badly affected in 1999. The fungal species involved include *Erysiphe cichoracearum* var. *cichoracearum* (on aster, cornflower, chrysanthemum and solidago); *Erysiphe aquilegia* (on aquilegia and larkspur); *Erysiphe knautiae* and *Sphaerotheca dipsacearum* on scabious; *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, more stems will be needed to make a saleable bunch.

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 three major cut flower families susceptible to powdery mildew (Compositae, Caryophyllaceae, 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 this second year, three approaches to the management of powdery mildew on solidago were devised and tested using seven fungicides.

MATERIALS AND METHODS

Site and crop details

The trials were undertaken on a commercial nursery at Spalding, Lincolnshire, using cv. Marvellous Gold a variety known to be susceptible to powdery mildew. Plants were grown in a 4-row beds at 35 x 35-38 cm spacing. The glasshouse trial was conducted on the second-cut crop.

Treatments

Outdoor crop

The disease management approach of each treatment is shown in bold type.

1. Untreated control
2. Thiovit, Dorado, Thiovit, Dorado, Thiovit, Dorado (spray every 14 days)
(“Low management input insurance programme 1”)
3. Thiovit twice within 21 days of emergence, Dorado (x2 within 7 days) immediately mildew is first seen in these plots, then revert to Thiovit at 7-day intervals, with a final spray of Dorado.
(“Disease monitoring programme 1”)
4. No sprays until mildew is first seen in these plots, then Dorado (x2 within 7 days), then Thiovit at 7 day intervals, and finish on Dorado
(“First symptoms programme 1”)
5. Thiovit, Twist, Twist, Thiovit, Thiovit, Thiovit (spray every 14 days)
(“Low management input insurance programme 2”)
6. Thiovit twice within 21 days of emergence, Systhane 6W (x2 within 7 days) immediately mildew is first seen in these plots, then revert to Thiovit at 7 day intervals
(“Disease monitoring programme 2”)
7. No sprays until mildew is first seen in these plots, then Systhane 6W (x2 within 7 days), then Thiovit at 7 day intervals and finish on Systhane 6W
(“First symptoms programme 2”)
8. Thiovit, Frupica, Thiovit, Frupica, Thiovit, Frupica every 14 days
(“Low management input insurance programme 3”)
9. Thiovit (2 g/l) + Agral (0.06 ml/l) applied at 14 day intervals
(“Low management input insurance programme 4”)
10. Thiovit (2 g/l) + Agral (0.06 ml/l) applied at 28 day intervals
(“Low management input insurance programme 5”)

The rates of fungicide used were: Dorado (20% pyrifenoX) at 0.25 ml/litre; Frupica (50% mepanipirim) at 800 g/ha; Thiovit (80% sulphur) + Agral at 2 g/litre + 0.06 ml/litre; Twist (15% trifloxystrobin) at 2.0 litres/ha and Systhane 6W (6% myclobutanil) at 1 g/l. Sprays were applied at 500 litres/ha (50 ml/m²), increasing with plant growth to 1,000 l/ha to maintain good coverage. For further information on the choice of products, please see Appendix 1.

Treatments were applied every 14 days starting within 2 weeks of re-growth, apart from treatments 4 and 7, where the first spray was to be triggered by the appearance of mildew. In practice, no sprays were applied to these treatments as no mildew occurred. The sequence of sprays applied is shown in Table 3.

Table 3. Sequence of fungicide treatments on solidago (outdoor trial) - 2001

Treatment	Sprays on outdoor trial ^b					
	1 30 Apr	2 14 May	3 31 May	4 11 Jun	5 25 Jun	6 9 Jul
1. Unt	-	-	-	-	-	-
2. LM1	Thiovit	Dorado	Thiovit	Dorado	Thiovit	Dorado
3. DM1	Thiovit	Thiovit	-	-	-	-
4. FS1	-	-	-	-	-	-
5. LM2	Thiovit	Twist	Twist ^a	Thiovit	Thiovit	Thiovit
6. DM2	Thiovit	Thiovit	-	-	-	-
7. FS2	-	-	-	-	-	-
8. LM3	Thiovit	Frupica	Thiovit	Frupica	Thiovit	Frupica
9. LM4	Thiovit	Thiovit	Thiovit	Thiovit	Thiovit	Thiovit
10. LM5	Thiovit	-	Thiovit	-	Thiovit	-

Unt - untreated; LM1 - low management programme 1; DM1 - disease monitoring programme 1; FS1 - first symptoms programme 1 etc.

^a Used twice in succession, rather than as an alternate spray with Thiovit, because of the 35 day harvest interval.

^b No mildew was seen in this trial, hence no sprays were applied to the first symptoms programmes, numbers 4 and 7.

Glasshouse crop

The disease management approach of each treatment is shown in bold type, followed by the abbreviated code used for that treatment in subsequent tables.

1. Untreated control (Unt)
2. Thiovit, Systhane 20 EW, Thiovit, Systhane 20 EW, Thiovit, Systhane 20 EW. Sprays every 14 days.
(Low management input insurance programme 1) (LM1)
3. Thiovit twice within 21 days of emergence, Systhane 20 EW (x2 within 7 days) immediately mildew is seen in these plots, then revert to Thiovit at 7 day intervals, finish on Systhane 20 EW
(Disease monitoring programme 1) (DM1)
4. No sprays until mildew is first seen in these plots, then Systhane 20 EW (x2 within 7 days), then Thiovit at 7 day intervals and finish on Systhane 20 EW
(First symptoms programme 1) (FS1)
5. Thiovit, Frupica, Thiovit, Frupica, Thiovit, Frupica. Sprays every 14 days.
(Low management input insurance programme 2) (LM2)
6. Thiovit twice within 21 days of emergence, Frupica (x2 within 7 days) immediately mildew is first seen in these plots, then revert to Thiovit every 7 days, and finish on Frupica
(Disease monitoring programme 2) (DM2)
7. No sprays until mildew is first seen in these plots, then Frupica (x2 within 7 days) then Thiovit at 7 day intervals and finish on Frupica
(First symptoms programme 2) (FS2)
8. Thiovit, Fungaflor, Thiovit, Fungaflor, Thiovit, Fungaflor. Spray every 14 days.
(Low management input insurance programme 3) (LM3)
9. Thiovit (2 g/l) + Agral (0.06 ml/l) applied at 14 day intervals
(Low management input insurance programme 4) (LM4)
10. Thiovit (2 g/l) + Agral (0.06 ml/l) applied at 28 day intervals
(Low management input insurance programme 5) (LM5)

Rates of fungicide used were: Thiovit (80% sulphur) + Agral at 2 g/litre + 0.06 ml/litre; Fungaflor (20% imazalil) at 0.5 ml/litre; Frupica (50% mepanipyrim) at 800 g/ha; and Systhane 20 EW (20.6% myclobutanil) at 0.45 litre/ha. The sprays were applied at 1,000 l/ha (100 ml/m²) increasing to 2,500 l/ha to maintain good crop cover. For further information on choice of products, please see Appendix 1.

The sequence of sprays applied is shown in Table 4.

Table 4. Sequence of fungicide treatments on solidago (glasshouse trial) - 2001

Treatment	30.7.01	6.8.01	13.8.01	20.8.01	29.8.01	03.9.01	10.9.01	17.9.01	24.9.01	1.10.01	8.10.01
1. Unt	-	-	-	-	-	-	-	-	-	-	-
2. LM1	Thiovit	-	Systhane	-	Thiovit	-	Systhane	-	Thiovit	-	Systhane
3. DM1	Thiovit	-	Thiovit	-	Systhane	Systhane	Thiovit	Thiovit	Thiovit	Thiovit	Systhane
4. FS1	-	-	-	-	Systhane	Systhane	Thiovit	Thiovit	Thiovit	Thiovit	Systhane
5. LM2	Thiovit	-	Frupica	-	Thiovit	-	Frupica	-	Thiovit	-	Frupica
6. DM2	Thiovit	-	Thiovit	-	Frupica	Frupica	Thiovit	Thiovit	Thiovit	Thiovit	Frupica
7. FS2	-	-	-	-	Frupica	Frupica	Thiovit	Thiovit	Thiovit	Thiovit	Frupica
8. LM3	Thiovit	-	Fungaflor	-	Thiovit	-	Fungaflor	-	Thiovit	-	Fungaflor
9. LM4	Thiovit	-	Thiovit	-	Thiovit	-	Thiovit	-	Thiovit	-	Thiovit
10. LM5	Thiovit	-	-	-	Thiovit	-	-	-	Thiovit	-	-

Unt - untreated; LM1 - low management programme 1; DM1 - disease monitoring programme 1; FS1 - first symptoms programme 1 etc.

Mildew was first observed in the crop on 17 August.

Experiment design and analysis

Each trial comprised a randomised block design with four (outdoor) or three (glasshouse) replicate blocks. There was double replication of the untreated control. Plot size for the outdoor trial was 1.7 m lengths of 1.2 m wide bed (2.04 m²). Plot size for the glasshouse trial was 1.1 m lengths of 1.2 m wide bed (1.32 m²). Disease control and crop yield assessment were conducted on stems within the central 1 m of the plot length. Results were examined by ANOVA, or another appropriate statistical test where initial examination of data showed that it is not suitable for ANOVA.

Assessments

During growth

1. Estimated % leaf area affected by powdery mildew (average of 3 positions in each plot).
2. Records were made of any leaf scorch, yellowing or stunting.

At harvest

Ten 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).
2. Length of stem.
3. Number of stems (of 10) still affected by powdery mildew after the normal removal of leaves on the basal 20 cm of stem. These were classed as unmarketable because of the mildew.
4. Weight of each of 10 stems/plot, after usual preparation for marketing.
5. Marketability. Plants deemed marketable were free from powdery mildew, or had only 1-2 small leaves affected which could be removed without detriment to appearance; had no chemical scorch or other pesticide damage; were within size and weight grades and were of good appearance (not thin or misshapen).
6. Spray deposit was assessed according to estimated % leaf cover; 0, nil; 1, 1-20%; 2, 21-40%; 3, 41-60%; 4, 61-80%; 5, 81-100%.

Crop diary

	<u>Field trial</u> <u>(first crop)</u>	<u>Glasshouse trial</u> <u>(second cut)</u>
Crop planted/cut down	--.04.01	16.07.01
Spray 1	30.04.01	30.07.01
Spray 2	14.05.01	13.08.01
Spray 3	31.05.01	29.08.01
Spray 4	11.06.01	03.09.01
Spray 5	25.06.01	10.09.01
Spray 6	09.07.01	17.09.01
Spray 7	-	24.09.01
Spray 8	-	01.10.01
Spray 9	-	08.10.01
Assessment 1	-	03.09.01
Assessment 2	-	08.10.01
Assessment 3	-	06.11.01

RESULTS AND DISCUSSION

Field trial

No powdery mildew occurred in the trial. The disease was not found on the nursery during this period. None of the fungicide programmes resulted in leaf scorch, stunted growth or had any other adverse effect on crop development.

Glasshouse trial

Powdery mildew was first observed in the crop on 17 August 2001, 4 days after spray 2 but increased only slowly to affect *c.* 1% leaf area on untreated plants by 8 October, when the final spray was applied (Table 5). The disease was initially restricted to leaves on the basal 30 cm of stem, but in the final 4 weeks it also appeared on leaves and stems near the tops of plants. All fungicide programmes appeared to reduce the disease and four of them resulted in freedom from powdery mildew at harvest 4 weeks after the final spray. These were treatments 2 (Thiovit/Systhane, low management), 4 (Systhane/Thiovit, first symptoms), 6 (Thiovit/Frupica, disease monitoring) and 7 (Thiovit/Frupica, first symptoms). No *Sclerotinia* or other diseases were observed in the crop.

The other treatments were almost as effective. The persistence of control from Fungaflor as a final spray (T8) was not as effective as that of Systhane 20EW or Frupica.

Stem length and weight were not significantly affected by fungicide treatments (Table 6).

All treatments resulted in a high proportion of marketable stems, except for the low management input insurance programme 5 (Thiovit sprays at 28 day intervals), where the final spray was applied 6 weeks before harvest and only 60% were marketable, a significant reduction.

There was a slight spray deposit visible on leaves at 4 weeks after the final spray, including from the water only spray (hard water area). The deposit from Frupica was slightly more obvious than that of other treatments, though in none was it sufficient to cause concern over marketability (Table 6).

The results of this work indicate three different approaches to management of solidago powdery mildew can be equally effective. Programmes based on regular crop monitoring with treatment from first symptoms, or a preventative spray soon after emergence followed by monitoring for first symptoms before spraying again, both have the potential to save on the number of fungicides applied, compared with a low management input insurance programme (routine sprays). However, in the protected crop trial reported here, where mildew occurred soon after crop emergence, it was the low management input insurance programmes (routine 14 day sprays) which resulted in the fewest sprays. These programmes need to be tested under conditions of greater disease pressure in order to better identify the advantages and disadvantages of each approach.

The reason for the relatively low disease severity encountered this year is uncertain. The same variety, cv. Marvellous Gold, was used in 2000, when 14% leaf area was affected by mildew at harvest, compared with 1% in 2001. Possibly the reduced disease severity in the trial crops was associated with the more effective control of mildew on other solidago crops on the host nursery.

Table 5. Effect of fungicide programmes on Solidago powdery mildew - protected crop, autumn 2001

Treatment	No sprays applied	Mean % leaf area affected			Mean no spots per stem
		3 Sep	8 Oct	6 Nov	6 Nov
1. Unt	0	0.32	0.74	1.09	50
2. LM1 (Thi/Sys)	6	0.06	0.03	0	0
3. DM1 (Thi/Sys)	9	0.01	0	0.01	0.03
4. FS1 (Sys/Thi)	7	0.10	0.02	0	0
5. LM2 (Thi/Fru)	6	0.13	0.06	0.01	0.13
6. DM2 (Thi/Fru)	9	0.09	0.04	0	0
7. FS2 (Kif/Thi)	7	0.04	0.01	0	0
8. LM3 (Thi/Fun)	6	0.24	0.05	0.01	0.63
9. LM4 (Thi/Thi)	6	0.38	0.21	0.01	0.13
10. LM5 (Thi/-)	3	0.33	0.02	0.04	2.63
Significance (21 df)		NS	NS	NS	0.009*
SED		-	-	0.49	-

Unt - Untreated; LM1 - low management programme 1; DM1 - disease monitoring programme 1; FS1 - first symptoms programme 1 etc.

Thi - Thiovit; Sys - Systhane 20EW; Fru - Frupica; Fun – Fungaflor

* Significant difference between treatments according to Friedman's test

Table 6. Effect of fungicide programmes on growth and appearance of Solidago - autumn 2001

Treatment	Stem length (cm)	Stem wt (g)	No stems marketable (of 10)	Spray deposit (0-5)
1. Unt	114.3	44.1	0	1.0
2. LM1 (Thi/Sys)	117.0	44.9	10	1.0
3. DM1 (Thi/Sys)	115.1	44.0	10	1.0
4. FS1 (Sys/Thi)	112.3	42.4	10	1.0
5. LM2 (Thi/Fru/	119.4	54.6	9	1.3
6. DM2 (Thi/Fru/	118.2	41.8	10	1.4
7. FS2 (Fru/Thi)	117.1	40.1	10	1.2
8. LM3 (Thi/Fun)	117.4	40.4	8	1.0
9. LM4 (Thi/Thi)	114.4	44.2	9	1.0
10. LM5 (Thi/-)	117.8	47.0	6	1.0
Significance (21 df)	NS	NS	***	*
SED	2.39	6.05	1.1	0.12

Unt - Untreated; LM1 - low management programme 1; DM1 - disease monitoring programme 1; FS1 - first symptoms programme 1 etc.

Thi - Thiovit; Sys - Systhane 20EW; Fru - Frupica; Fun - Fungaflor

*, *** Significantly differences between treatments at P< 0.05 and 0.001 respectively.

CONCLUSIONS

1. Three approaches to management of solidago powdery mildew were devised and tested. Mildew occurred in the glasshouse trial and all the programmes gave effective control. The approach based on disease monitoring for first symptoms has the potential to save on the number of sprays needed for effective control, though this is not necessarily the case if mildew occurs soon after crop emergence. Also, this technique is reliant on good, thorough and regular (at least weekly) crop monitoring, so action can be taken as soon as the early symptoms are seen
2. Fungaflor applied as the final spray in a programme gave less persistent control of mildew during flower harvest than Systhane 20EW and Frupica.
3. Fungicides permitted for use on solidago, which are active against powdery mildew and are safe to the crop are summarised (Table 1). Example programmes for effective disease control with minimum risk of causing crop damage or selecting mildew-resistant strains are given (Table 2).

TECHNOLOGY TRANSFER

1. 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.
2. Presentation by Tim O'Neill at HRI/HDC Cut Flower Conference, HRI Kirton, April 2000.
3. Cut flower mildew control programmes. *HDC News* **71**, 8 (News reports).

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Appendix 1

Notes on treatment selections

1. Thiovit was chosen over Bravo 500 (or other chlorothalonil products) as a protectant because of its greater activity against mildew (year 1 result) and as it is less expensive.
2. Dorado was chosen as a mildew-specific fungicide for the outdoor trial following excellent results with it in year 1, and reports of good control on other ornamental crops in consultancy work.
3. Systhane 20EW was chosen as the EBI - group mildew specific fungicide for protected crops, rather than Dorado, because the latter will not be permitted on protected crops after 31 July 2002. Systhane 20 EW is in the same fungicide group as Dorado and also performed well in year 1.
4. Twist was chosen as the strobilurin fungicide for outdoor crops because of good results in year 1 when the same active ingredient (trifloxstrobin) when used as Flint. However, it has now become known that Flint will not be marketed in the UK, but Twist is already available, though with a 35-day harvest interval. The strobilurin is a different fungicide group to Dorado, and had broad-spectrum activity.
5. No strobilurin fungicide was used on the protected crop. At the time the trials commenced, Amistar was the only strobilurin product permitted on crops under protection, but this product is known to have relatively poor powdery mildew activity. As an alternative to the EBI group (Systhane), the anilinopyrimidine fungicide mepanipyrim, which has good activity against both powdery mildew and botrytis was used. Mepanipyrim was used in the trials as an experimental material (Kif 3535). it received Approval for use on protected crops in January 2002, and is now available for use by growers as Frupica. Kif 3535 and Frupica have exactly the same active ingredient (50% mepanipyrim), so the name Frupica is used throughout the report to aid clarity.
6. Three mildew-specific fungicides were thus being tested in each trial:

<u>Outdoor</u>	<u>Protected</u>
Dorado (EBI)	Systhane 20EW (EBI)
Frupica (Anilinopyrimidine)	Frupica (Anilinopyrimidine)
Twist (Strobilurin)	Fungaflor (EBI)
7. Nimrod-T was not included because of its relatively poor results in year 1.
8. Wherever possible (ie harvest interval permitting), the final spray in each programme was with a mildew-specific fungicide rather than the Thiovit, to optimise longer protection from systemic activity (where present), and to avoid risk of sulphur smell on the harvested product.
9. After the trials began, a label approval for use of the strobilurin fungicide Strobly WG on protected ornamentals became available.