Project title:	Narcissus: evaluation of fungicides for improved control of smoulder and white mould
Project number:	BOF 072
Project leader:	Malcolm Millar (to November 2011) Tim O'Neill (from December 2011)
Report:	Final Report, August 2012
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Key staff:	Malcolm Millar, ADAS David Lockley, ADAS Stuart Wale, SAC Roger Griffin-Walker, SAC
Location of project:	Commercial sites, Cornwall and Aberdeenshire
Industry representatives:	Mr Mark Clark, Grampian Growers Ltd., Logie, Montrose, Angus DD10 9LD Mr Dick Evenden, H L Hutchinson Ltd, Pinchbeck, Spalding, Lincs PE11 3PJ
Date project commenced:	1 December 2010
Expected completion:	30 November 2012

DISCLAIMER

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

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

Dr Tim O'Neill

Horticultural Research Manager

ADAS

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

Report authorised by:

Dr Barry Mulholland

Head of Horticulture

ADAS

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

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GROWER SUMMARY

Headline

- New fungicides identified for improved white mould control.

Background and expected deliverables

Smoulder (*Botrytis narcissicola*) and white mould (*Ramularia vallisumbrosae*) of narcissus attack flower buds and leaves resulting in a loss of marketable flowers and reduced bulb yield. The diseases are most common in commercial crops left down for two years or more, as widely practiced in the UK for economic reasons. Both diseases are favoured by wet weather and are likely to increase in importance with the forecast warmer, wetter winters due to climate change. The use of effective fungicides for control of these diseases is critical as the crop generally only justifies a limited number of sprays. Ground conditions in the spring can restrict the opportunity to spray, further increasing the need to select effective products. Choice of the most appropriate fungicides is currently unclear due to loss of some proven effective materials (e.g. carbendazim as Cleancrop Curve, vinclozolin as Ronilan) and the phased cessation of the Long Term Arrangements for Extension of Use (LTAEU) which allowed extrapolation from other crops. There is concern that repeated use of a restricted number of fungicides (e.g. azoxystrobin, iprodione) will inevitably lead to selection of resistant strains of the causal fungi. Novel fungicides recently introduced on arable crops may offer improved control of foliar diseases. The overall aim of the project is to identify new fungicide treatments for control of narcissus smoulder and white mould so that an armoury of effective products is maintained as older products are withdrawn. At the end of Year 1 the project was amended to introduce work on the effect of different spray timings.

The expected deliverables from this project are increased knowledge on:

- The efficacy of some new fungicides against smoulder and white mould;
- The safety of these fungicides to narcissus and whether they affect two disorders (‘rust’ and ‘chocolate spot’) of unknown cause;
- The effect of some different spray timings on disease control.

Summary of the project and main conclusions

Aberdeenshire trials

A replicated experiment was established in Aberdeenshire in autumn 2010 in a first-year-down commercial crop of the variety Carlton. In 2011, 11 fungicides were each applied three times from immediately after flowering (Figure 1a). White mould increased greatly during wet weather in June and affected 17% leaf area by the end of the month. All treatments significantly reduced the disease and eight products reduced it to 2% leaf area affected or less: Amistar (azoxystrobin), Brutus (epoxiconazole + metconazole), Comet (pyraclostrobin), Escolta (cyproconazole + trifloxystrobin), Nativo 75WG (tebuconazole + trifloxystrobin), Prosaro (prothioconazole + tebuconazole), Shirlan (fluazinam) and Tracker (boscalid + epoxiconazole). Plots treated with Tracker remained free of the disease. All of the fungicides greatly increased green leaf retention compared with untreated plants, probably due mainly to foliar disease control.

In 2012 the experiment was continued. Each main plot was divided into three sub-plots comprising: a) no further (2012) fungicide sprays; b) 3 sprays post-flowering; c) 2 sprays pre-flowering and 3 sprays post-flowering. The aims were to determine the effect of year 1 fungicide treatment on disease levels at the start of year 2, and the benefit of adding pre-flowering sprays to a programme of post-flowering sprays, for each of the fungicides tested.

White mould appeared in late April 2012 and increased to affect 25% leaf area of untreated plants by 12 June. Disease severity was significantly reduced by all fungicides except for Amistar. Five fungicides reduced the disease by 50% or more (Brutus, Comet, Prosaro, Shirlan and Tracker). In this crop, where white mould did not appear until near the end of flowering, disease control from three post-flowering sprays was not significantly improved by the addition of two pre-flowering sprays. Tracker again gave the best control of white mould and also resulted in the greatest retention of green leaf area (Figure 1d).

The level of smoulder was low throughout the season (2% severity or less) and none of the treatments reduced the disease.

There was no evidence that fungicides applied in 2011 affected initial levels of white mould in 2012.

Cornwall trials

A replicated experiment identical to that in Aberdeenshire was established in Cornwall in autumn 2010 in a first-year-down crop of the variety Golden Ducat. Smoulder and white mould were observed at low levels in April 2011. Smoulder increased to affect up to 3.6%

of leaf area but none of the fungicides reduced the disease. As the smoulder symptoms were largely primary infections (i.e. ones that arose from the bulb or soil), this lack of effect of fungicides on early season smoulder was expected. White mould did not develop early season due to dry weather. Unbeknown to the host farmer, the stock of bulbs was badly affected by Fusarium basal rot resulting in gappy crop growth and early die-back. The effect of treatments on smoulder and white mould later in the season could not be determined because of early senescence due to Fusarium basal rot.

The original site in Cornwall was therefore abandoned due to the poor crop growth. In 2012 a new trial was established on a second-year-down crop of variety Early Flame (Figure 1b). Each main plot was divided into two sub-plots comprising: a) 3 sprays post-flowering, b) 2 sprays pre-flowering and 3 sprays post-flowering. The aim was to determine the effect of adding pre-flowering sprays to a programme of post-flowering sprays for each fungicide tested. The fungicides examined comprised eight that performed well against white mould in 2011 and four products not tested previously in this project with a nil or short harvest interval. These were Karamate Dry Flo Neotec (mancozeb), Scala (pyrimethanil), Signum (boscalid + pyraclostrobin) and Switch (cyprodinil + fludioxonil).

White mould was present at low levels from mid-February. By late April 2012 white mould had increased to affect 9% leaf area on untreated plants (Figure 1c). All 12 fungicides significantly reduced severity of the disease, with six treatments (Brutus, Folicur, Prosaro, Signum, Tracker and Vivid) reducing it to 1% leaf area affected or less. In this crop where white mould was not observed before the start of flower picking, disease control from three post-flowering sprays was only slightly improved by the addition of two pre-flowering sprays.

Smoulder was present from emergence and increased slightly to affect 2% leaf area on untreated plants. All fungicides except Karamate Dry Flo Neotec (mancozeb) reduced the disease. Prosaro and Tracker gave the best control. At 7 weeks after the final spray, these two treatments, which also gave best control of white mould, had the greatest green leaf area.

A low level of the disorder ‘chocolate spot’ (unknown cause) occurred at the Aberdeenshire site in 2011; levels were not reduced by any of the fungicide treatments. No phytotoxic symptoms were observed following fungicide treatment at either site in either year.

Figure 1: Narcissus fungicide experiments 2012. a) View of Aberdeenshire site (top left), b) Cornwall site (top right), c) severe white mould (bottom left) and d) prolonged green leaf area in plots treated with Tracker (bottom right).

Table 1: Details of fungicides evaluated for control of smoulder and white mould

Product	Active ingredients (fungicide group)	Rate used (kg or L/ha)	Approval status (August 2012)	Max. no sprays*	Harvest interval (days)
Amistar	azoxystrobin (11)	1.0	SOLA 0443/09	Not stated[a]	Not stated
Brutus	epoxiconazole (3) + metconazole (3)	3.0	LTAEU	3	Not stated
Cercobin WG	thiophanate-methyl (1)	1.0	SOLA 1384/08 (expired 28/2/11)	2	Not stated
Comet 200	pyraclostrobin (11)	1.0	LTAEU	2	Not stated
Escolta	cyproconazole (3) + trifloxystrobin (11)	0.35	LTAEU	2	35
Folicur	tebuconazole (3)	1.0	LTAEU[b]	2	28
Karamate Dry Flo Neotec	mancozeb (M3)	2.0	Label	4	Not stated
Nativo 75WG	tebuconazole (3) + trifloxystrobin (11)	0.4	LTAEU	2	21
Priori Xtra	azoxystrobin (3) + cyproconazole (11)	1.0	LTAEU	2	30
Prosaro	prothioconazole (3) + tebuconazole (3)	1.2	LTAEU	2	56
Scala	pyrimethanil	2.0	SOLA 1315/11	3	3
Shirlan	fluazinam (29)	0.4	LTAEU	10	0
Signum	boscalid (7) + pyraclostrobin (11)	1.35	SOLA 1852/09	2	Not stated
Switch	cyprodinil (9) + fludioxonil (12)	1.0	Label	3	Not stated
Tracker	boscalid (7) + epoxiconazole (3)	1.5	LTAEU	2	Not stated
Vivid	pyraclostrobin (11)	1.0	LTAEU	2	Not stated

*Treatments in this project were applied under an Experimental Permit to permit up to five sprays of each product. [a]Maximum total dose of 4 L/ha. [b]Extrapolation under the Long Term Arrangements for Extension of Use (LTAEU) from SOLA 1516/04 which permits Folicur on narcissus grown for galanthamine production.

Where a product is used under a SOLA or the LTAEU, growers should read and observe all the restrictions; treatment is at a grower's own risk.

Table 2: Summary of fungicide efficacy on narcissus white mould determined in field trials in 2011 and 2012[a]

Product	Aberdeenshire			Cornwall	
	2011 (3 sprays)	2012 (3 sprays)	2012 (4 sprays)	2012 (3 sprays)	2012 (5 sprays)
Untreated	17.4	25.3	25.3	8.6	8.6
Amistar*	1.9	19.0	17.0	2.1	2.4
Brutus*	0.3	4.8	3.8	1.2	0.5
Escolta	0.3	11.3	8.5	2.0	1.0
Folicur	2.4	7.3	6.0	1.2	0.4
Karamate*	-	-	-	4.9	4.8
Nativo 75WG	0.2	13.3	11.0	1.1	0.8
Priori Xtra	3.7	18.5	15.0	-	-
Prosaro	0.2	7.0	5.3	0.5	0.1
Scala*	-	-	-	2.4	0.9
Shirlan*	0.4	6.5	4.3	-	-
Signum*	-	-	-	0.9	0.4
Switch*	-	-	-	3.5	1.4
Tracker*	0	2.8	1.5	0.8	0.1
Vivid*	0.6	7.3	5.0	1.6	1.4

[a] Products where use is no longer permitted on narcissus (August 2012) have been excluded.

* Product has a harvest interval of 7 days or less. Comet 200 was used instead of Vivid at the Aberdeenshire site; the two products have the same active ingredient.

Financial benefits

Annual losses of narcissus bulb and flower production due to foliar diseases vary greatly between crops and years. The effect of foliar diseases on bulb yield is probably underestimated as foliar die-back due to disease is not easily distinguished from that of early senescence due to other causes (e.g. moisture deficit). Assuming that foliar diseases on average reduce marketable bulb yield by 10%, and flower production by 5%, and with an estimated farmgate value of £11 million and £15 million for narcissus bulb and flower production respectively in 2011, it is estimated that losses each year are in excess of £1.85 million.

Action points for growers

- For crops susceptible to white mould, consider applying up to three fungicide sprays from immediately after flower picking using two or more of the following products: Brutus, Escolta, Folicur, Nativo 75WG, Priori Extra, Prosaro, Shirlan, Signum, Tracker or Vivid (or Comet 200). Karamate Dry Flo Neotec, Scala and Switch also give some control but were generally slightly less effective.
- If Amistar is used for white mould control, monitor crops carefully and consider using a fungicide from a different group if disease control is below expectations.
- Use products with active ingredients from different fungicide groups (see Table 1) for sequential sprays against white mould in order to reduce the risk of selecting fungicide resistant strains. Example programmes which fit this criterion are:
    - Signum, Prosaro, Signum.
    - Tracker, Switch, Tracker
- In crops where no white mould is observed before flower picking starts, there appears to be little benefit in applying pre-flowering sprays for this disease providing a programme of three effective treatments is applied starting from immediately post-flowering.
- Where the risk of white mould is assessed as high (consider site, variety and crop history, for example), and weather restricts the number of spray days, it would be prudent to apply at least one spray pre-flowering.
- Note that any harvest interval specified on a label applies to both flower and bulb harvest. Where there is no specified harvest interval, it is permissible to treat this as a zero harvest interval.
- In crops where flowers will be picked and a pre-flowering fungicide spray is considered necessary, select a product with a nil or no stated harvest interval for this treatment. Do not use Shirlan or equivalent product at this time due to risk of allergic contact dermatitis.

SCIENCE SECTION

Introduction

The narcissus foliar diseases smoulder (*Botrytis narcissicola*) and white mould (*Ramularia vallisumbrosae*) can cause significant reductions in the number of marketable flowers and bulb yield. With a forecasted increase in environmental conditions that favour the growth of these pathogens due to climate change, and only a limited number of sprays economically justifiable, the choice and use of fungicides for leaf disease control is critical. The aim of this work was to identify new fungicide treatments for control for narcissus smoulder and white mould so that an armoury of effective products is maintained as older products are withdrawn. The specific objectives were: i) to determine the efficacy of candidate fungicides for control of narcissus white mould and smoulder; ii) to establish the efficacy of candidate fungicides used during one year's growth in controlling the occurrence of smoulder primary symptoms at the start of the flowering year; iii) to determine the relative efficacy of fungicides in reducing infection within a season; iv) to monitor these fungicides for crop safety and for any effect on the disorders 'rust' and 'chocolate spot' (unknown cause).

At the end of Year 1, it was requested that the Year 2 work be amended to include an evaluation of the effect of different spray timings. The field experiments were consequently amended to investigate the effect of adding two pre-flower harvest sprays to a programme of three post-flower harvest sprays.

Materials and methods

Site and crop details

Two similar experiments were established in commercial crops of narcissus. One was in a crop of cv. Carlton at Briggs of Criddie, Drumlithe, Aberdeenshire, the second was in a crop of Early Flame at Rosudgeon, Penzance, Cornwall. These varieties were chosen as being susceptible to smoulder and white mould. At the Aberdeenshire site the soil was a sandy loam (freely drained), pH 6.2, and previous crops were winter barley (2010), spring barley (2009), potatoes (2008) and winter wheat (2007). At the Cornwall site the soil was a sandy loam, pH 7.2. The previous crops were potatoes (spring 2010) and winter barley (2009). Bulbs (9-10 cm) were planted and the crops grown according to normal commercial practice with the exception that no fungicides were applied to the trial areas. A crop diary for each site is given in Appendix 1.

At the Aberdeenshire site, treatments in 2012 were applied to the same plots as in 2011. The trial in Cornwall was established in a second year down crop at a new site in 2012 as the crop used in 2011 was badly affected by Fusarium basal rot.

Treatments

Aberdeenshire site

Nine fungicides were evaluated in comparison with two industry standards, Amistar and Folicur (Table 3). In 2011 the whole of each plot was sprayed with the appropriate fungicide. In 2012 plots were divided into three sub-plots that were treated as follows: a) no sprays in 2012; b) three sprays from immediately after full flowering; c) two sprays pre-flowering and three sprays post-flowering. Sprays were applied at intervals of 2-6 weeks (Appendix 1). Products were used at the full recommended rate.

Cornwall site

Nine fungicides were evaluated in comparison with three industry standards; Amistar, Folicur and Karamate Dry Flo Neotec (Table 4). Each plot was divided into two sub-plots that were treated as follows: a) three sprays from immediately after flower picking; b) two sprays pre-flower harvest and three sprays from immediately post-flower harvest. Sprays were applied at intervals of 2-3 weeks (Appendix 1). The different spray timings examined at each site are summarised in Table 5. Products were used at the full recommended rate. Fungicides were applied using a calibrated CO_2 assisted knapsack sprayer, with nozzle LD02 F110 medium spray quality (2.5 bar) with 2 m boom.

Table 3: Details of fungicide treatments – Aberdeenshire, 2012

Treatment	Active ingredient(s)	Rate of use (kg or L/ha)
1. Untreated	-	-
2. Amistar*	azoxystrobin (250 g/L)	1.0
3. Brutus	Epoxiconazole + metconazole (37.5 + 27.5 g/L)	3.0
4. Cercobin WG	thiophanate methyl (70% w/w)	1.0
5. Escolta	cyproconazole + trifloxystrobin (163 + 375 g/L)	0.35
6. Folicur*	tebuconazole (250 g/L)	1.0
7. Nativo 75WG	tebuconazole + trifloxystrobin (50 + 25% w/w)	0.40
8. Priori Xtra	azoxystrobin + cyproconazole (200 + 80 g/L)	1.0
9. Prosaro	prothioconazole + tebuconazole (125 + 125 g/L)	1.2
10. Shirlan	fluazinam (500 g/L)	0.4
11. Tracker	boscalid + epoxiconazole (233 + 67 g/L)	1.5
12. Comet 200	pyraclostrobin (200 g/L)	1.0

* Industry standards.

Table 4: Detail of fungicide spray treatments – Cornwall, 2012

Treatment	Active ingredient(s)	Rate of use (kg or L/ha)
1. Untreated	-	-
2. Amistar*	azoxystrobin (250 g/L)	1.0
3. Brutus	epoxiconazole + metconazole (37.5 + 27.5 g/L)	3.0
4. Escolta	cyproconazole + pyraclostrobin (163 + 375 g/L)	0.35
5. Folicur*	tebuconazole (250 g/L)	1.0
6. Karamate*	mancozeb (75% w/w)	2.0
7. Nativo 75WG	tebuconazole + trifloxystrobin (50 + 25% w/w)	0.4
8. Prosaro	prothioconazole + tebuconazole (125 + 125 g/L)	1.2
9. Scala	pyrimethanil (400 g/L)	2.0
10. Signum	boscalid + pyraclostrobin (26.7 + 6.7% w/w)	1.35
11. Switch	cyprodinil + fludioxonil (37.5 + 25% w/w)	1.0
12. Tracker	boscalid + epoxiconazole (233 + 67 g/L)	1.5
13. Vivid	pyraclostrobin (250 g/L)	1.0

* Industry standards.

Table 5: Detail of fungicide spray timings applied in 2011 and 2012 at two sites to crops assessed in 2012

Site	2011 Whole plots	2012 Sub-plots
Aberdeenshire (2 year trial)	3 sprays post-flowering of the test products	a) Nil b) 3 sprays post-flowering c) 2 sprays pre- and 3 post-flowering
Cornwall (1 year trial)	Commercial programme (5 sprays)	a) 3 sprays post-flowering b) 2 sprays pre- and 3 post-flowering

Experimental design and statistical analyses

At each site the experiment was done as a fully randomised block design replicated four times; there was double replication (8 plots) of the untreated. Plots were two ridges wide and 10 m long with one row left between blocks. At the Aberdeenshire site, each main plot was sub-divided into three sub-plots (3.3 m long); at the Cornwall site, each main plot was sub-divided into two sub-plots (5 m long). Data were examined by analysis of variance, treating the designs as split plots with products on whole plots and timings on split plots. The analyses were done as: control + (product x timings).

Disease assessments

The central 2.5 m (Aberdeenshire) or 4 m (Cornwall) of the two ridges of each sub-plot was assessed for disease at intervals as the diseases increased in untreated plots. Initially, a count was made of the numbers of leaves or plants in each sub-plot affected by white mould or smoulder. Subsequently disease was assessed at four random points as % leaf area affected by white mould and / or smoulder and % green leaf area (% GLA). The presence of other diseases such as narcissus fire (*Botrytis polyblastis*), and the disorders ‘chocolate spot’ and ‘rust’, were noted.

Results and discussion

Crop growth and the dates of spray application were around 2-3 months later at the Aberdeenshire site than at the Cornwall site, as expected (Table 6). At both sites, smoulder occurred at low levels while white mould was severe.

Table 6: Dates of fungicide spray application and first observation of leaf diseases – 2012

Aberdeenshire site		Cornwall site	
Sprays applied	Diseases present	Sprays applied	Diseases present
Pre flower pick			
1. March 1	Smoulder	1. January 10	Nil
2. March 20	Smoulder	2. January 24	Smoulder
Post flower pick			
3. April 5	Smoulder	3. February 16	White mould + smoulder
4. May 2	White mould + smoulder	4. March 1	White mould + smoulder
5. June 14	White mould + smoulder	5. March 20	White mould + Smoulder

Aberdeenshire site

In 2012 smoulder was first noted in the crop on 1 March. The number of plants affected on 16 March, when one spray had been applied, was 3% or less across all treatments. Although there was a trend for less disease on plots treated with Brutus, Nativo 75WG and Comet 200 (0.3% plants affected), there were no significant differences between treatments ($p > 0.05$) (Table 7). The smoulder did not increase further as the season progressed and no further assessments were made.

White mould was first observed in the crop on 30 April and increased to affect 25% leaf area of untreated plants by 12 June. Disease severity was reduced by all fungicides except for Amistar (24% leaf area affected), and was little reduced by Cercobin WG, Priori Xtra and Nativo 75WG (23%, 21% and 19% leaf area affected respectively) (Table 7). Tracker (9%) was the most effective treatment, as in 2011. Comet, Shirlan, Prosaro, Folicur and Escolta (12-15% leaf area affected) were almost as good as the two best treatments.

Combining data for all fungicide products, on 12 June the mean severity of white mould on sub-plots treated with two sprays (the three spray programme) was no greater than that on sub-plots treated with four sprays (the five spray programme) (10.7% and 9.0% respectively) (Table 7). Both programmes resulted in large reductions in white mould severity compared with sub-plots left untreated in 2012 (27.3% leaf area affected). There was no evidence that plots left untreated in 2011 and 2012 (25.3%) had greater white mould than plots left untreated in 2012 only (27.3%) i.e. there was no evidence that failure to control white mould one year resulted in greater white mould the following year. Data for

individual plots is shown in Appendix 4. The final spray was delayed due to wet weather. It was not possible to assess white mould on 4 July, three weeks after the fifth and final spray, due to the high level of leaf senescence in most plots. In part, green leaf area can be taken as a measure of white mould control by the five spray programmes (see below).

Table 7. Effect of fungicide product and spray timing on narcissus leaf diseases – Aberdeenshire, 2012

Treatment	Number plants with smoulder	% leaf area affected by white mould		% green leaf area	
	16 March	30 April	12 June	12 June	4 July
Maximum number sprays applied by this date:	1	3	4	4	5
Fungicide products					
1. Untreated	2.4	0.8	25.3	31.0	1.2
2. Amistar	1.0	1.0	23.7	39.8	2.1
3. Brutus	0.3	0.4	10.9	68.3	5.0
4. Cercobin WG	3.0	2.2	22.8	36.5	1.8
5. Escolta	0.8	0.5	14.8	58.5	4.6
6. Folicur	0.8	0.4	13.8	61.3	2.1
7. Nativo 75WG	0.3	0.7	19.3	53.2	2.8
8. Priori Xtra	1.3	0.5	21.2	47.1	2.2
9. Prosaro	1.0	0.5	12.4	65.0	3.8
10. Shirlan	1.3	0.5	12.3	67.8	31.2
11. Tracker	1.5	0.4	8.8	75.6	54.8
12. Comet 200	0.3	0.6	12.2	68.7	4.6
Significance (40 df)	NS	<0.001	<0.001	<0.001	<0.001
LSD vs untreated	-	0.74	3.55	3.10	1.46
LSD between treatments	-	0.64	4.10	3.58	1.69
Fungicide timing					
Untreated (2011 and 2012)	-[a]	0.8	25.3	31.0	1.2
Nil in 2012 (sprayed in 2011)	-	1.1	27.3	32.7	1.5
Three sprays in 2012	-	0.5	10.7	68.9	14.9
Five sprays in 2012	-	0.4	9.0	73.4	14.9
Significance (36 df)	-	<0.001	<0.001	<0.001	<0.001
LSD vs untreated	-	0.44	2.42	1.52	0.96
LSD between treatments	-	0.33	1.83	2.09	0.64

[a] Data too sparse for analysis. NS - no significant difference.

Table 8. Effect of fungicide product and spray timing on white mould severity (% leaf area affected) – Aberdeenshire, 12 June 2012

Fungicide product	Number of sprays applied by 12 June 2012		
	Nil	3	4
1. Untreated	25.3	-	-
2. Amistar	35.0	19.0	17.0
3. Brutus	24.3	4.8	3.8
4. Cercobin WG	26.8	19.8	22.0
5. Escolta	24.5	11.3	8.5
6. Folicur	28.3	7.3	6.0
7. Nativo 75WG	33.8	13.3	11.0
8. Priori Xtra	30.0	18.5	15.0
9. Prosaro	25.0	7.0	5.3
10. Shirlan	26.3	6.5	4.3
11. Tracker	22.0	2.8	1.5
12. Comet 200	24.3	7.3	5.0
Significance (20 df)		0.017	
LSD vs untreated		4.75	
between products x timings		6.08	
between products within one timing column		5.62	

For most individual fungicides, it appeared that in 2012 the addition of two fungicide sprays pre-flowering to a programme of two sprays post-flowering (the third post-flowering spray had yet to be applied) appeared to result in a slightly greater reduction of white mould but differences were not statistically different (Table 8). Within the set of three-spray applications, Brutus, Folicur, Prosaro, Shirlan, Tracker and Comet were all significantly ($p = 0.017$) better than Amistar, Cercobin WG and Priori Xtra (and the untreated). In this examination of the data, Amistar sprays result in a small but significant reduction in white mould (from 25% to 17-19% leaf area affected). The greater levels of white mould on sub-plots treated in 2011 with Amistar and left untreated in 2012 (35%) compared with plots left untreated in both years (25%) is puzzling. Possibly this is a spurious result. Or possibly this fungicide controlled other microorganisms that reduce the quantity of *R. vallisumbrosae* persisting from one year to the next.

All fungicides resulted in significantly greater ($p < 0.001$) green leaf area on 12 June compared with untreated plants. The effect was greatest with Tracker (76%), Comet 200

(68%), Brutus (68%), Shirlan (68%), Prosaro (65%), Folicur (61%) and Escolta (59%). These are the seven fungicides that also resulted in greatest control of white mould. On 4 July, 3 weeks after the final spray, plots treated with Tracker (55%) and Shirlan (31%) were still clearly green, whereas all other treatments had 5% green leaf area or less (Table 7). Five sprays were no better than three sprays for retaining green leaf area for any of the treatments (data not shown).

The possible effect of white mould severity in a crop at the end of one year influencing incidence of the disease in the same crop at the start of the following year was further examined by regression analysis for individual plot data. The percentage variation accounted for was only 3%, indicating no relationship. Data for smoulder were too few to permit a similar examination for this disease.

Cornwall site

White mould was first noted in the trial in February 2012, at the start of flower picking. At an assessment on 14 March (Appendix 2) the mean number of white mould lesions on 8 m ridge lengths of untreated plants, comprising several thousand leaves, was 14-21. There were no significant differences between treatments at this stage, although there was a trend to fewer white mould lesions with Amistar, Brutus, Prosaro, Signum, Tracker and Vivid.

By 4 April, just 2 weeks after the final spray, white mould affected 4.3% leaf area on untreated plants. Disease severity was significantly reduced ($p < 0.001$) by all treatments, with Brutus, Folicur, Prosaro, Tracker and Vivid reducing it to 0.2% or less (Table 9). Switch (1.7% leaf area affected) and Karamate Dry Flo Neotec (2.1%) were less effective than most other treatments.

By 26 April, white mould had increased to affect 8.6% leaf area on untreated plants (Table 9). Disease severity was significantly reduced by all treatments, with six products (Brutus, Folicur, Nativo 75WG, Prosaro, Signum and Tracker) reducing it to 1% or less. Prosaro remained the most effective treatment (0.3% leaf area affected).

Combining data for all fungicide products, at two weeks after the final spray the mean severity of white mould on sub-plots treated with five sprays was slightly and significantly ($p < 0.001$) less than on sub-plots treated with three sprays at both assessment dates (Table 9). For individual fungicides, Switch was the only product where spray number significantly affected control of white mould, five sprays being better than three (Table 10). This product, primarily marketed for control of Botrytis diseases, is less effective against white mould than all the other fungicide tested which probably explains the effect of spray number; the better fungicides were able to provide good control with just three applications. Prosaro

(prothioconazole + tebuconazole) resulted in the least white mould in both the three-spray post-flowering programmes (0.05% leaf area infected) and the five-spray pre- and post-flowering programmes (0.01% leaf area infected). At five weeks after the final spray, none of the individual products resulted in better control when applied as a programme of five sprays compared with three sprays (Table 10).

Overall these results indicate good activity from a wide range of products containing triazole and/or strobilurin fungicides against *R. vallisumbrosae*. The older fungicide pyrimethanil also showed very useful activity. The results also show that there is little, if any, benefit to be gained from applying fungicides pre flower harvest for control of white mould where the disease is not present in a crop at the start of flower picking, providing a programme of effective treatment is applied from immediately after flower picking.

At the first assessment on 14 March, smoulder affected just four leaves per 8 m length of untreated plants. The severity of smoulder on 4 April remained low with less than 1% leaf area affected in untreated plots (Table 9). None of the fungicide treatments had significantly reduced the disease ($p > 0.05$) at this time, even though several of the products tested were chosen because of their known good activity against *Botrytis* diseases (i.e. Folicur, Scala, Signum and Switch). By 26 April the disease had increased slightly to affect 2% leaf area on untreated plants (Table 9). This low level of disease was significantly reduced ($p < 0.003$) by all treatments except Karamate Dry Flo Neotec (mancozeb). Prosaro and Tracker were jointly the most effective treatment (0.1% leaf area affected). The number of fungicide sprays applied had no significant effect on smoulder severity ($p > 0.05$) (Table 11). Most of the smoulder lesions present were leaf tip and leaf margin lesions, considered to be primary symptoms that arise as leaves emerge. It is therefore expected that fungicide treatments would not reduce this smoulder symptom.

All treatments increased green leaf area at 5 weeks after the final spray compared with the untreated control (86% GLA) (Table 9). The treatments giving very good control of white mould also resulted in the greatest green leaf area, at around 95-98% GLA. At 7 weeks after the final spray, green leaf area had fallen to 36% on untreated plants and remained above 90% on plants treated with Brutus, Escolta, Folicur, Prosaro, Signum, Tracker and Vivid; Signum and Tracker were the most effective. Amistar was relatively poor compared with other treatments, having 76% green leaf area.

By 13 June, 11 weeks after the final spray, Tracker still had 80% green leaf area, Signum was 15% and all other treatments had nil

Table 9: Effect of fungicide product and spray timing on narcissus leaf diseases – Cornwall, 2012

Treatment[a]	Mean % leaf area affected				Green leaf area	
	Smoulder		White mould			
	4 April	26 April	4 April	26 April	26 April	11 May
Fungicide products						
1. Untreated	0.8	1.9	4.3	8.6	86.3	36.3
2. Amistar	0.3	0.3	0.5	2.2	95.4	75.9
3. Brutus	0.8	0.4	0.1	0.8	98.0	92.5
4. Escolta	0.8	0.4	1.1	1.5	97.3	91.4
5. Folicur	0.6	0.3	0.2	0.8	97.8	92.6
6. Karamate	0.6	1.3	2.1	4.8	89.6	65.5
7. Nativo 75WG	0.8	0.4	0.6	0.9	97.7	88.1
8. Prosaro	0.2	0.1	<0.1	0.3	98.9	94.4
9. Scala	1.1	0.5	0.8	1.7	96.6	89.6
10. Signum	0.1	0.3	0.4	0.7	98.5	97.1
11. Switch	0.9	0.2	1.7	2.5	96.1	82.4
12. Tracker	0.3	0.1	0.2	0.4	98.8	97.4
13. Vivid	0.5	0.4	0.2	1.5	96.7	94.9
Significance (40 df)	NS (p>0.05)	0.003	<0.001	<0.001	<0.001	<0.001
LSD vs control	-	0.89	1.77	2.08	3.10	10.85
LSD between treatments	-	1.03	1.53	2.40	3.58	12.52
Fungicide timing [b]						
Three sprays	0.7	0.38	0.8	1.84	96.3	87.5
Five sprays	0.5	0.40	0.5	1.17	97.3	89.4
Significance (36 df)	NS (p>0.05)	NS (p>0.05)	0.001	0.001	0.009	<0.001
LSD	-	-	0.19	0.39	0.69	1.02

[a] Sprays were applied between 10 January and 20 March.

[b] Analysis excludes untreated. NS – no significant differences.

Table 10: Comparison of treatment efficacy using three sprays and five sprays of each fungicide – Cornwall, 4 April 2012 (two weeks after final spray)

Treatment	Mean % leaf area affected by:			
	Smoulder		White mould	
	3 sprays	5 sprays	3 sprays	5 sprays
1. Untreated[a]	(0.75)	(0.75)	(4.31)	(4.31)
2. Amistar	0.34	0.25	0.53	0.48
3. Brutus	0.84	0.75	0.11	0.03
4. Escolta	0.53	1.00	1.41	0.82
5. Folicur	0.81	0.31	0.38	0.07
6. Karamate	1.06	0.16	1.76	2.39
7. Nativo 75WG	1.25	0.31	0.38	0.82
8. Prosaro	0.34	0	0.05	0.01
9. Scala	1.50	0.75	1.13	0.44
10. Signum	0.16	0.13	0.78	0.03
11. Switch	0.57	1.19	2.63	0.70
12. Tracker	0.19	0.44	0.31	0.09
13. Vivid	0.44	0.47	0.36	0.11
Significance (33 df)	NS (p >0.05)		0.001	
LSD	-		0.821	

[a] Analysis excluded untreated. NS – no significant differences.

Table 11: Comparison of treatment efficacy using three sprays and five sprays of each fungicide – Cornwall, 26 April 2012 (five weeks after final spray)

Treatment	Mean % leaf area affected by:			
	Smoulder		White mould	
	3 sprays	5 sprays	3 sprays	5 sprays
1. Untreated[a]	(1.72)[a]	(2.01)	(8.75)	(8.44)
2. Amistar	0.13	0.44	2.06	2.38
3. Brutus	0.44	0.44	1.19	0.50
4. Escolta	0.44	0.38	2.00	1.03
5. Folicur	0.06	0.50	1.19	0.38
6. Karamate	1.25	1.43	4.88	4.75
7. Nativo 75WT	0.25	0.56	1.13	0.75
8. Prosaro	1.13	0.13	0.53	0.06
9. Scala	0.75	0.19	2.44	0.88
10. Signum	0.50	0.06	0.88	0.44
11. Switch	0.13	0.20	3.53	1.41
12. Tracker	0.06	0.19	0.75	0.13
13. Vivid	0.44	0.31	1.56	1.38
Significance (33 df)	NS (p >0.05)		NS (p >0.05)	
LSD	-		-	

[a] Analysis excludes untreated. NS – no significant differences.

Comparison of sites

A comparison of the two sites with regard to crop growth stage, weekly rainfall, timing of fungicide spray application, occurrence of white mould on untreated plants and remaining green leaf area is summarized in Table 12. By calendar date (week number), the Cornish crop was five weeks ahead of the Scottish crop at the 15-25 cm growth stage, seven weeks ahead at mid-flowering, and five weeks at around 30% crop senescence. The first two spray treatments in Cornwall were applied at a slightly earlier crop growth stage than in Scotland, reflecting local practice in Cornwall of ensuring early growth is protected due to the high risk of poor weather preventing spray treatment in response to disease occurrence. Sprays 3 (mid flower harvest) and 4 (end of flowering) were applied at around the same growth stage at the two sites. The final spray at the Cornwall site was applied 3 weeks after spray 4, whereas that at the Scotland site was applied 6 weeks after spray 4, at the start of crop senescence having been delayed due to frequent rain (Appendix 5).

White mould occurred earlier in the Cornish crop (mid-flower harvest, week 7) than in the Scottish crop (end of flowering, week 18). The disease developed relatively slowly in Cornwall, increasing from <1% to 9% over 10 weeks, compared with an increase from 1% to 25% over 6 weeks in the Scottish crop. The total rainfall, number of rain days and mean temperature during the 6 week period from 1% white mould were no greater in Aberdeenshire than in Cornwall suggesting that other factors (e.g. wind, varietal susceptibility) may account for the more rapid disease development in the Aberdeenshire crop.

Table 12. Comparison of growth stages (GS), fungicide spray, timings, level of white mould and green leaf area in untreated plots and weekly rainfall at trial sites – 2012

Week number	Aberdeenshire					Week number	Cornwall				
	GS	Spray number	% white mould	% GLA	Weekly rainfall (mm)		GS	Spray number	% white mould	% GLA	Weekly rainfall (mm)
9	20-25 cm	1			-	2	10 cm	1			1.0
10					-	3					2.8
11					-	4	15-25 cm	2			24.8
12	50 cm	2			0.2	5			0		23.0
13					0	6					18.0
14	60% flowers open	3			16.6	7	Mid flower harvest	3	<1%		4.6
15					6.2	8					4.4
16					17.8	9	10% flowers left	4			15.6
17					12.0	10					4.2
18	10% flowers left	4	1%	98%	6.2	11			1%		5.8
19					14.7	12		5			1.0
20					13.7	13					0
21					0	14			4%		6.4
22					6.3	15					31.6
23					30.5	16					34.2
24	Early senescence	5	25%	31%	9.3	17			9%	86%	82.6
25					47.5	18					13.8
26					26.0	19	Early senescence			36%	26.4
27				1%	4.3	20					8.2

Conclusions

Fungicides for control of foliar diseases

1. A wide range of fungicide products currently provide good control of white mould (*R. vallisumbrosae*). In this project we demonstrated large and significant reductions with 14 products. Many of the effective products contain triazoles (4), strobilurins (2) or triazole/strobilurin mixtures (3). Tracker (boscalid + epoxiconazole) was the best or joint best product in all three experiments.
2. There is evidence that the performance of Amistar (azoxystrobin) against white mould is declining with respect to other available products. In previous work (1990s), this fungicide gave the best control of white mould out of the products tested; in the current work, Amistar gave good control in one experiment (2011), relatively good control in a second (2012) and poor control in a third (2012).
3. A low level of smoulder (2% leaf area affected) was reduced by 12 fungicides. The most effective products were Folicur, Signum, Switch, Prosaro and Tracker, all of which reduced disease to 0.3% or less.
4. None of the fungicide tested in this work (Amistar, Brutus, Cercobin WG, Escolta, Folicur, Karamate Dry Flo Neotec, Nativo 75WG, Priori Xtra, Prosaro, Scala, Shirlan, Signum, Switch, Tracker, Vivid or Comet 200) caused any obvious symptoms of damage to the growing crop.

Spray timing

5. A programme of three sprays of fungicides active against white mould (see above) applied from immediately after flower harvest is likely to provide adequate control of the disease in crops where the disease does not occur pre-flowering. We found only a small benefit in applying an additional two pre-flowering sprays in such crops.

Persistence of smoulder and white mould

6. We found no evidence that the level of white mould towards the end of cropping one year influenced the level of the disease in the same crop at the start of the following year.
7. Levels of smoulder in this work were too low to draw any firm conclusions on the persistence of smoulder in a crop between one season and the next.

Harvest interval

8. The Chemicals Regulations Directorate (CRD) confirmed that the harvest interval restriction on a product used under the LTAEU applies to both the flower harvest and bulb harvest.
9. Where no harvest interval is stated on a label or SOLA/EAMU, CRD confirmed that this can be treated as a zero harvest interval with respect to flower picking for field grown narcissus.

References

Anon. (2003). Narcissus leaf diseases: forecasting and control of smoulder and white mould. Final Report for HortLINK project HL0188.

O'Neill, T.M., Hanks, G.R. & Wilson, D. (2004). Control of smoulder disease (*Botrytis narcissicola)* in narcissus with fungicides. *Annals of Applied Biology* 145:129-137.

Technology transfer

Presentations

Evaluation of fungicides for improved control of smoulder and white mould. HDC Narcissus Technical Seminar. 14 April 2011, Spalding, Lincs and 5 May 2011, Camborne, Cornwall.

Articles

Two-site trial for narcissus fungicides. *HDC News* **170**, p.9 (New projects).

O'Neill T M & Millar M (2012). Holding on to control of leaf disease. *HDC News*, **180**, 20-23.

O'Neill TM (2012). Battling white mould. *HDC News* (in press).

Site demonstration

Demonstration of Cornwall trial to some BOF panel members and growers – Malcolm Millar, 21 May 2012.

Appendix 1 Crop diaries, 2012

Cornwall site

Date	GS	Action	Initials
30/11/2011		Trial area selected and plots marked out – 10m x 4 rows. Trial area is 8 plots wide	MM & DL
		(28.85m) x 70m = 0.202ha. Crop is about to emerge. Plot ends marked with white	
		pegs; plot centres marked with blue pegs.	
14/12/11		Labelled all plots and set up EasyLogger. Wet & windy 5°C, hail shower	MM & DL
5/1/12		Crop at 90% emergence	MM
10/1/12	0-18cm	Applied first series of sprays to sub-plots A (i.e. sub plots nearest to the track) in	MM & DL
	(Average	perfect conditions.	
	10cm)	Weather: Cloudy; 11.5 – 12.6°C; wind very light, 0.9 – 0.1 m/s.	
		All plots assessed for smoulder primaries. Three possible primaries found in plots	
		21, 23 & 55. Shoot counts made on 1.0m row at 5 points across the trial:	
		66; 79; 40; 68; 87 – Mean 68 shoots per metre of row.	
24/1/12	15-25cm	Applied second series of sprays to sub-plots A.	MM & DL
		Weather: Cloudy but dry. 10.6 - 11.5°C; wind 0.6 – 1.8 m/s	
2/2/12		Flowers 30cm. No disease	MM
13/2/12		First flower pick	MM
16/2/12		Picked flowers in sub-plots of treatments with long harvest intervals. All other plots	MM & DL
		picked by grower gang.	
		Applied third series of sprays to whole plots. Weather: Dry, mainly cloudy, a few	
		sunny spells. 9.5 – 11.5°C; wind 0.1 – 0.5 m/s. White mould now relatively easy to	
		find at low levels	
27/2/12		Grower gang picked flowers from split plot.	MM
1/3/12		Picked flowers from un-picked sub-plots.	MM & DL
		Applied 4th series of sprays to whole plots. Weather: Dry, calm, sunny.	
		15.5 – 17.6°C; wind 0.1 – 0.6 m/s.	
		Some further development of white mould. Photographed symptoms.	
		Note: a problem developed while spraying the Brutus treatments – drop in pressure	
		and fluctuating pressure. It is likely that this treatment received a lower than	
		intended dose. The problem appeared to be associated with a faulty spray can.	
9/3/12		Assessed al sub-plots for smoulder (number of plants affected) and white mould	MM & DL
		(number of leaves infected) in the central two rows per sub-plot. White mould is	
		mainly confined to leaf tips at the moment. Dry, overcast 11°C.	
20/3/12		Applied 5th series of sprays to whole plots. Weather: cloudy, very little wind; dry, but	MM & DL
		occasional drizzle before spraying although crop dry for spraying.	

		12.7 – 13.3°C; wind 0.0 – 0.5 m/s.	
		Counted the number of leaves in five 1m lengths of row in the centre two rows of four	
		four untreated plots (one plot per replicate). Downloaded met data.	
4/4/12		Assessed all plots for white mould and smoulder: % leaf area affected at two points	MM & DL
		in each of the central two rows per sub-plot. Cold, heavy showers.	
26/4/12		Assessed % white mould, % smoulder and % green leaf area at two points in each of	MM & DL
		the central two rows per sub-plot. Although the white mould had increase	
		substantially in some untreated plots, many sprayed plots still had little disease and	
		plenty of green leaf area. Dry after a period of heavy rain.	

Aberdeenshire site

Date	GS	Action
1/3/12	20-25 cm	Spray 1 (some flower buds visible)
16/3/12		All plots assessed – smoulder present
20/3/12	50 cm	Spray 2 (a few buds nearly open)
5/4/12	60% flowers open	Spray 3
30/4/12		All plots assessed – white mould present
2/5/12	10% flowers remaining	Spray 4
12/6/12		All plots assessed
14/6/12	Early senescence	Spray 5
4/7/12		All plots assessed

Appendix 2 Interim disease assessment – Aberdeenshire

30 April 2012

Treatment	Mean % leaf area affected by white mould[a]		
	Number sprays applied		
	Nil	3	3
1. Untreated	0.8	-	-
2. Amistar	1.2	1.4	0.4
3. Brutus	0.3	0.6	0.4
4. Cercobin WG	2.6	1.9	2.1
5. Escolta	1.3	0.1	0.1
6. Folicur	0.9	0	0.3
7. Nativo 75WG	1.3	0.4	0.4
8. Priori Xtra	0.7	0.4	0.3
9. Prosaro	0.9	0.1	0.4
10. Shirlan	0.9	0.4	0.1
11. Tracker	1.0	0.2	0.1
12. Comet 200	1.3	0.2	0.3
Significance (20 df)		NS	

[a] Untransformed data shown; analysis was done on log transformed data. NS – no significant differences.

Appendix 3 Interim disease assessment – Cornwall

14 March 2012

Treatment	Mean number leaves affected[a]			
	Smoulder		White mould	
	2 sprays	4 sprays	2 sprays	4 sprays
1. Untreated	4	4	21	14
2. Amistar	1	2	8	5
3. Brutus	3	3	8	3
4. Escolta	3	3	23	8
5. Folicur	2	3	17	14
6. Karamate	3	4	23	15
7. Nativo 75WG	4	4	31	10
8. Prosaro	4	3	8	3
9. Scala	4	3	10	9
10. Signum	3	3	26	3
11. Switch	4	4	25	12
12. Tracker	2	2	9	5
13. Vivid	3	2	6	4
Significance (43 df)	NS		NS	
LSD	-		-	

[a] Untransformed data shown; analysis was done on log transformed data. NS – no significant differences.

Appendix 4 Occurrence of white mould untreated sub-plots in 2012 in relation to fungicide treatment and levels in 2011 – Aberdeenshire site

Plot	Treatment in 2011	White mould (% leaf area)		
		29 June 2011	30 Apr 2012	12 June 2012
1	Pro	0.2	2	25
2	Ami	0.2	1	30
3	Bru	0.1	1	28
4	Pri	4.2	0	35
5	Shi	0.1	0	20
6	Unt	14.2	0.1	22
7	Nat	0.4	2	40
8	Cer	4.8	3	25
9	Esc	0.4	0.5	25
10	Unt	22.0	0	25
11	Fol	2.3	1	18
12	Com	0.5	0	15
13	Tra	0	1	25
14	Bru	0.3	0	23
15	Pri	3.5	1	25
16	Com	0.6	1	22
17	Unt	19.6	1.5	23
18	Esc	0.3	0	20
19	Fol	0.5	0.5	35
20	Nat	0.4	1	25
21	Shi	0.9	2	20
22	Unt	11.8	1	25
23	Cer	4.9	3	22
24	Tra	0	1.5	18
25	Ami	1.5	2	50
26	Pro	0.2	0.5	25
27	Tra	0	1	25
28	Unt	13.2	1	25
29	Fol	3.8	1	25
30	Ami	4.0	0.4	25

31	Cer	4.8	3	30
32	Bru	0.1	0	24
33	Nat	0	1.5	40
34	Pri	5.4	1	30
35	Unt	25.0	0.7	25
36	Shi	0.4	0.5	35
37	Pro	0.3	0	30
38	Esc	0.2	0.5	28
39	Com	0.7	0	20
40	Shi	0.2	1	30
41	Fol	2.8	1	35
42	Unt	22.0	0.5	40
43	Ami	1.8	1.5	35
44	Pro	0.2	1	30
45	Nat	0	0.5	30
46	Cer	4.4	1.5	30
47	Pri	1.6	0.8	30
48	Bru	0.7	0	22
49	Esc	0.2	4	25
50	Unt	11.2	1.5	30
51	Com	0.6	4	40
52	Tra	0	0.5	20

See Table 3 for full names of fungicide products.

Appendix 5 Summary of weather data – 2012

Aberdeenshire				Cornwall			
Week no.	Total rainfall (mm)	No. rain days	Mean temperature (ºC)	Week no.	Total rainfall (mm)	No. rain days	Mean temperature (ºC)
9	-	-	-	**2**	1	2	7.8
10	-	-	-	3	2.8	4	9.1
11	-	-	-	**4**	24.8	6	7.5
12	0.2	1	6.9	5	23	4	3.5
13	0	0	9.7	6	18	4	4.3
14	16.6	6	3.5	**7**	4.6	2	8.1
15	6.2	6	5.1	8	4.4	5	8.9
16	17.8	6	5.0	**9**	15.6	4	9.2
17	12	6	5.4	10	4.2	2	9.0
18	6.2	1	6.2	11	5.8	3	8.1
19	14.7	3	7.8	**12**	1	1	10.3
20	13.7	4	6.7	13	0	0	10.6
21	0	0	16.2	14	6.4	5	7.6
22	6.3	1	10.4	15	31.6	6	8.0
23	30.5	3	11.4	16	34.2	6	8.5
24	9.3	3	10.1	17	82.6	6	9.0
25	47.5	5	12.3	18	13.8	2	9.9
26	26	5	13.4	19	26.4	4	10.7
27	4.3	1	13.2	20	8.2	2	10.1

Weeks when sprays were applied are shown in bold.