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Project leader:	Dr Tim O'Neill
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Location of project:	Commercial site, Cornwall
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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

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Signature .... Date ....

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GROWER SUMMARY

Headline

The fungicides Signum, Tracker and Vivid applied post-flowering to narcissus delayed senescence in the year of application and increased flower yield by up to 44% the following year.

Background and expected deliverables

Foliar diseases remain a major threat to narcissus production, with the potential to reduce both flower and bulb yield. In 2012 white mould (*Ramularia vallisumbrosae*) was widespread and occasionally severe in all the main narcissus producing areas in the UK. In some crops it caused premature senescence despite the use of several fungicide sprays. BOF 72 identified several new fungicides that are very effective against white mould and markedly delayed leaf senescence. Information gained on the efficacy of new products against smoulder (*Botrytis narcissicola*) was limited due to low disease levels. The aims of this project were to further improve control of foliar diseases and to determine the effect of some fungicide sprays on flower yield. Specific objectives were:

1. To determine if foliar fungicides applied one year affect occurrence of smoulder primaries the following year;
2. To determine if foliar fungicides that delay senescence one year affect flower numbers produced the following year;
3. To determine if *R. vallisumbrosae, Botrytis* species or other fungi are associated with leaves showing rapid dieback but no obvious white mould or smoulder symptoms;
4. To carry out a desk top exercise to devise some example fungicide programmes for control of foliar diseases.

Summary of the project and main conclusions

Objective 1 – Effect of foliar fungicides applied one year on smoulder primaries the following year

A replicated field experiment on cv. Early Flame in Cornwall, established and treated with different fungicides in 2012, was left unsprayed with fungicides in 2013. Although a low level of smoulder (up to 2% leaf area affected) was recorded in the crop in 2012, no smoulder primaries occurred in 2013, indicating conditions were not suitable for infection of shoots by *B. narcissicola* during emergence. As such, authors cannot draw any definitive conclusion

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as to whether fungicides applied in year one influence the occurrence of smoulder primaries the follow year.

Levels of white mould in 2013 were affected by fungicides applied the previous year. On 27 February 2013, shortly after the end of flower picking, white mould severity was significantly reduced by eight fungicides compared with the untreated (2.5% leaf area affected). Nativo 75WG (tebuconazole + trifloxystrobin), Tracker (boscalid + epoxiconazole) and Vivid (pyraclostrobin) were most effective, reducing white mould to 0.3% leaf area affected. These fungicides all significantly reduced white mould in 2012 from 9% leaf area affected to 1.5% or less. This result suggests that good control of white mould one year reduces the risk of severe disease in the crop early in the following year.

Objective 2 – Effect of foliar fungicides that delay senescence on flower numbers the following year

In the same crop of cv. Early Flame, six fungicide treatments that delayed foliage senescence in 2012 were examined for their effect on flower numbers in 2013. Green leaf area on 11 May 2012 ranged from 65% (Karamate Dry Flo Neotec) to 97% (Tracker) on fungicide treated crop, compared with just 36% on untreated crop. The mean number of flower bunches picked in February 2013 was significantly increased by Signum (boscalid + pyraclostrobin), Tracker and Vivid, by 44, 27 and 22% respectively compared with crop left untreated in 2012 (Figure 1). Green leaf area in 2012 was significantly associated with numbers of flower bunches picked in 2013, accounting for 55.3% of the variation in flower yield.

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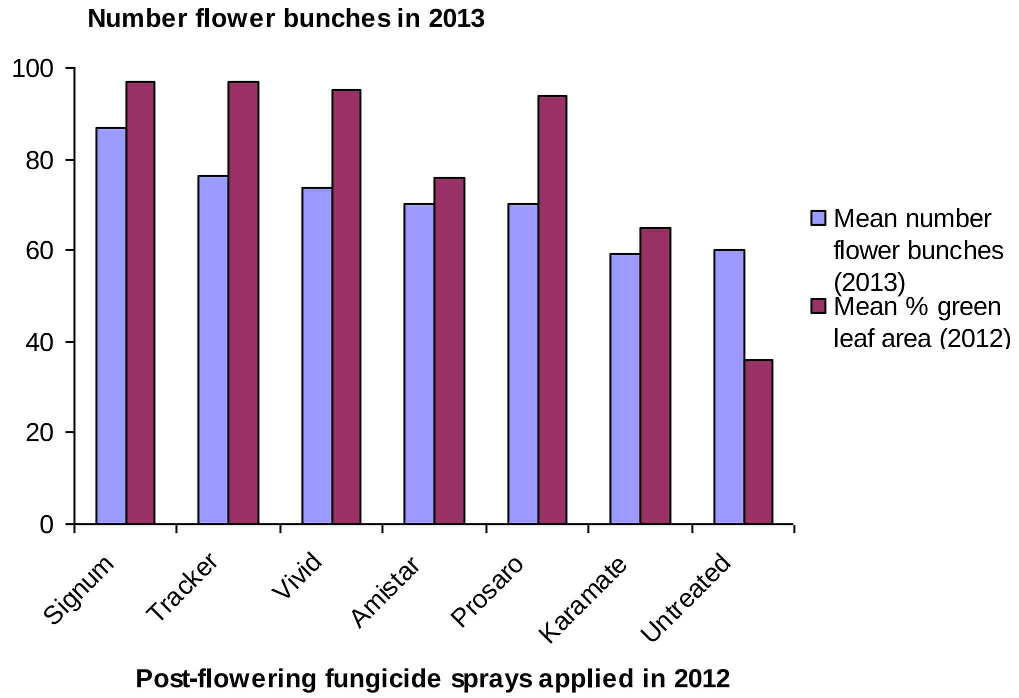

Figure 1. Effect of post-flowering fungicide sprays (x3) applied in 2012 on narcissus green leaf area (11 May 2012) and flower number the following year (February 2013)

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a) b)

c) d)

Figure 2: Narcissus experiment in Cornwall, 2013, a) View of trial site; b) white mould symptoms before flower picking; c) comparison of plot showing differences in white mould severity; d) White mould lesion with sclerotia of *R. vallisumbrosae* just visible.

Objective 3 – Association of R. vallisumbrosae, B. narcissicola and other fungi with narcissus crops showing rapid dieback and no obvious foliar disease

There were few reports of rapid crop dieback in 2013. Samples were collected from a crop showing patches of foliage dieback in Lincolnshire in June 2013. On laboratory examination, the necrotic leaves were found to contain one or several pale brown oval

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lesions; *B. narcissicola* was consistently isolated from these lesions. Further samples would need to be examined to determine whether *Botrytis* is consistently associated with these symptom types and can be implicated as a causal agent.

Objective 4 – Example fungicide programmes

Details of fungicides permitted for use on narcissus and with useful activity against white mould and/or smoulder are summarised in Table 1. The relative activity of these products against white mould and smoulder as determined in trials undertaken in BOF 072 and BOF 072a is given in Table 2. Based on this information, example fungicide spray programmes for control of narcissus foliar diseases were devised (Table 3). The programmes are all designed to comply with label restrictions, reduce the risk of selecting resistant strains of *R. vallisumbrosae* and *B. narcissicola*, provide effective control of white mould and smoulder and delay leaf senescence. Other effective programmes using different products could be devised. The timing of fungicide sprays in a programme should be made according to interval since last treatment, disease pressure (determined by crop monitoring) and opportunities to spray. Where early lifting is required, it would be prudent not to apply a late spray of a fungicide that greatly delays leaf dieback.

Potential fungicide options for control of leaf scorch (*Stagonospora curtisii*) were examined by reference to field trials on control of glume blotch on wheat (*Stagonospora nodorum*). Good control of *S. nodorum* was given by Amistar, Twist (trifloxystrobin) and Vivid. Vivid at half dose gave control equivalent to or better than a full dose of most other fungicides tested. Triazole/strobilurin fungicide products showed a small improvement over triazoles alone. Based on these results it is suggested that fungicides likely to provide good control of narcissus scorch include Amistar, Signum, Tracker and Vivid; Bravo 500 (chlorothalonil) used as a protectant also provides some control. A fungicide programme designed to control white mould, smoulder and scorch was devised (Table 3).

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Table 1: Details of fungicides permitted for use on narcissus (August 2013) and with activity against smoulder and white mould

Product	Active ingredients (fungicide group)	Maximum rate of use (kg or L/ha)	Approval status (August 2013)	Max. no sprays	Harvest interval (days)
Amistar	Azoxystrobin (11)	1.0	SOLA 0443/09	Not stated[a]	Not stated
Bravo 500	chlorothalonil (M5)	2.0	SOLA 1130/11	1	Not stated
Brutus	epoxiconazole (3) + metconazole (3)	3.0	LTAEU	3	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	EAMU 2141/12	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	SOLA 2884/08	2	Not stated

[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, EAMU or the LTAEU, growers should read and observe all the restrictions; treatment is at a grower's own risk.

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Table 2. Relative efficacy of some fungicides against narcissus white mould (*Ramularia vallisumbrosae*) and smoulder (*Botrytis* spp.) based on trials results in BOF 072, BOF 072a and elsewhere

Product	Relative efficacy against white mould		Relative efficacy against *Botrytis* spp.	
	BOF 72	BOF 072a	BOF 72	Other trials
Amistar	***	***	*****	*
Brutus	*****	*	****	NT
Escolta	****	****	***	***
Folicur	*****	*	*****	***
Karamate	***	****	**	NT
Nativo 75WG	****	*****	****	NT
Priori Xtra	***	NT	NT	NT
Prosaro	***	****	*****	NT
Rovral WG	NT	NT	NT	***
Scala	****	*	****	***
Shirlan	*****	NT	NT	***
Signum	*****	****	*****	***
Switch	****	*	*****	****
Tracker	*****	*****	*****	NT
Vivid	*****	*****	****	NT

* 0-20%. ** 21-40%; *** 41-60%; ****61-80%; ***** 81-100% control. NT – not tested.

BOF 072 – calculated from the mean results of 2-5 trials for white mould, 2 for smoulder.

BOF 072a – effect of fungicides one season on white mould at flowering the following season.

Other trials – relative efficacy of those fungicides used against *Botrytis* spp. in other crops.

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Table 3. Example fungicide spray programmes for narcissus leaf diseases

	Pre-flowering sprays		Post-flowering sprays				
	1	2	3	4	5	6	7
<u>First-year down, no flowers cropped</u>							
A.	-	Karamate	Signum	Karamate	Tracker	-	-
B.	Karamate	Signum	Folicur	Signum	Folicur	Tracker	-
<u>Second-year down, flowers cropped</u>							
C.	-	Signum	Folicur	Signum	Tracker	-	-
D.	Karamate	Signum	Folicur	Vivid	Tracker	Vivid	-
<u>High *Stagonospora* risk (eg Tazetta varieties/Isles of Scilly), flowers cropped</u>							
E.	-	Signum	Bravo 500	Vivid	Tracker	Vivid	-
F.	Bravo	Signum	Folicur	Vivid	Tracker	Vivid	Tracker

Example 'guideline' programmes A-D are designed for management of white mould and smoulder; programmes E-F for these diseases and leaf scorch. There are numerous other programmes that could be devised using these and/or other fungicides. Varietal susceptibility, disease occurrence in a crop and forecast weather should also be used to inform product choice and spray timing.

The interval between sprays will be determined by interval since last treatment, disease pressure (determined by crop monitoring) and opportunities to spray. Where early lifting is required, it would be prudent not to apply a late spray of a fungicide that delays leaf dieback.

Financial benefits for growers

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.

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Action points for growers

- For narcissus crops where flowers will be harvested the following year, consider applying one or more sprays of Signum, Tracker or Vivid in the current year to delay leaf senescence and increase future flower yield.
- It is likely that other fungicides which give good control of foliar diseases and delay leaf dieback will also increase flower yield.
- Where a crop will be left down for another year, apply fungicide sprays after flowering to prevent late-season build up of white mould. Amistar, Escolta, Karamate Dry Flo Neotec, Nativo 75WG, Prosaro, Signum, Tracker and Vivid applied post flowering in 2012 all reduced the occurrence of white mould in early 2013.
- Examination of the literature on a related disease indicates that Amistar, Signum, Tracker and Vivid are likely to provide some control of leaf scorch (*Stagonospora curtisii*)
- In addition to cost, consider the following aspects when selecting fungicide products for use in a programme to control foliar diseases: efficacy against white mould, smoulder and leaf scorch; maximum number of permitted sprays; harvest interval; rotation of products from different fungicide groups to reduce the risk of resistance development.
- Example spray programmes for different situations are given in Table 3.
- Monitor occurrence of foliar diseases in crops to inform spray decisions (product choice and spray timing).
- An application was made to CRD for an off-label approval (EAMU) for use of Tracker, post-flowering, on outdoor narcissus.

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SCIENCE SECTION

Introduction

In BOF 72 only limited information was gained on the efficacy of new fungicides against smoulder (*Botrytis narcissicola*) due to a relatively low incidence of the disease in all experiments. In a further attempt to gain information for little additional effort, the Cornwall fungicide trial from BOF 72 was maintained into 2013 in order to determine if fungicides applied for smoulder control in 2012 affected the incidence of smoulder primaries in 2013.

Several foliar fungicides used in BOF 72 markedly delayed crop senescence. Previous work has shown that some foliar fungicides that prolong green leaf retention can increase marketable bulb yield by up to 50% (O'Neill, Hanks & Wilson, 2004). An observation study on a crop cv. Carlton in 2012, where untreated plants were severely affected by white mould (*Ramularia vallisumbrosae*), indicated that sprays of Tracker (boscalid + epoxiconazole) increased bulb yield by 70% compared with untreated plots. The effect of foliar fungicides that prolong retention of photosynthetic tissue on narcissus flower yield is unknown. Large differences between fungicide treatments in crop senescence were observed at the Cornwall trial in 2012. The aim of work in this project was to determine if any of the fungicide treatments that delayed senescence in 2012 also increased numbers of marketable flowers in 2013.

In 2012, several growers reported some narcissus crops showed very rapid foliage dieback with no obvious white mould or smoulder symptoms. The aim of work in this project was to examine some crops during dieback and determine occurrence of *Botrytis species, R. vallisumbrosae* and any other fungal pathogens associated with dieback symptoms.

Selection of fungicides for use on narcissus to control smoulder and white mould is influenced by: efficacy, price, spectrum of activity, resistance risk, harvest interval, maximum permitted number of sprays/total dose and possibly other factors. The aim of the work in this project was to: i) review the fungicides available for potential use as foliar sprays on narcissus and tabulate their key features and ii) devise some example fungicide programmes using products that have good activity, are likely to remain available in the near future and are at low risk of selecting resistant strains of *Botrytis* species and *R. vallisumbrosae.*

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Materials and methods

Site and crop details

The experiment was established in 2012 in a two-year-down crop of Early Flame at Rosudgeon, Penzance, Cornwall. The soil was a sandy loam, pH 7.2 with previous crops of potatoes (spring 2010) and winter barley (2009). Bulbs (9-10 cm) were planted in autumn 2010 at 14.4 t/ha (6 t/acre) and grown according to normal commercial practice, with the exception that no fungicides were applied to the trial area in 2012 or 2013.

Treatments

Nine novel fungicides and three industry standards (Amistar, Folicur and Karamate Dry Flo Neotec) were applied three times (16 February, 1 March and 20 March 2012) from immediately post-flower harvest (Table 4). Products were used at their full recommended rate and applied using a CO_2 assisted knapsack sprayer with nozzle LD02F110 medium spray quality (2.5 bar) and with a 2 m boom. No fungicides were applied in 2013 until after the end of flower harvest when the experiment had concluded.

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

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

* Industry standards.

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Experiment design and statistical analyses

The experiment was a randomised block design with four replicate blocks and double replication (8 plots) of the untreated. Plots were 2 ridges wide and 10 m long with one unsprayed row left between blocks. A 4 m long section of each plot (x 2 ridges) was used for disease and flower yield assessments. Results were examined by analysis of variance and regression analysis. Data on numbers of leaves affected were log transformed before analysis.

Disease and related assessments

The crop was examined in 2013 every 2-3 weeks from emergence to the end of flower harvest. Full disease assessments were undertaken on 28 January and 7, 15 and 27 February. Initially, a count was made of the numbers of leaves or shoots affected by white mould and smoulder. Plants were also examined for stunted growth, leaf yellowing or distorted growth, to check for any phytotoxicity from the novel fungicide treatments applied the previous year. The number of leaves in 10 x 1 m lengths of ridge in untreated plots was counted to give a measure of crop density.

Flower numbers

Flowers were picked at the normal pencil bud stage from all plots of seven treatments. The seven treatments chosen were those that gave the widest possible range of differences in crop senescence as measured by % green leaf area assessed on 11 May 2012: untreated (36%), Karamate Dry Flo Neotec (65%), Amistar (76%), Prosaro (94%), Vivid (95%), Signum (97%) and Tracker (97%). All marketable flowers were harvested on 7, 9, 12 and 15 February 2013 and the numbers of bunches (of 10 stems) were recorded.

Early dieback

Narcissus leaf samples showing ‘early dieback’ were requested from industry representatives This problem, noted in 2012, has patches of plants developing leaf yellowing from the tip and dying quickly with the flower stalks remaining green. In 2013 samples were examined by direct microscope observation of affected leaves and by isolation from leaves, after surface disinfection, onto potato dextrose agar. Ten leaves were examined for each sample.

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Results and discussion

Objective 1 – Effect of foliar fungicides applied one year on smoulder primaries and the following year

At the time of assessment, the crop was in its third-year-down and a dense canopy of leaves and shoots developed. No smoulder symptoms were recorded between first emergence and 2 weeks after the end of flower harvest in 2013, even though smoulder was confirmed in the crop the previous year. The factors determining severe outbreak of smoulder are complex and not fully understood. Frequent rain alone is not a guarantee of severe smoulder as found in BOF 72 in 2012. Factors considered to affect occurrence of smoulder primary symptoms (i.e. symptom development arising as shoots emerge) include inoculum potential (quantity of *B. narcissicola* within a bulb), soil type, temperature and moisture at shoot emergence, level of crop damage (from flower picking) and duration of leaf wetness. The crop was picked in 2012 and was subject to frequent rain both in 2012 and 2013. Possibly there were insufficient frosts and soil movement during early growth in 2013 to cause physical damage at shoot emergence, which is considered to increase the risk of smoulder.

White mould was first observed on 7 February when shoots were around 20 cm tall and increased by 27 February 2013 to affect 2.5% leaf area on plants untreated in 2012. Although no fungicides were applied to the crop in 2013, there were significant differences between treatments ($p < 0.001$) according to the fungicides used in 2012. Eight fungicides (Amistar, Escolta, Karamate Dry Flo Neotec, Nativo 75WG, Prosaro, Signum, Tracker and Vivid) reduced white mould severity to 1.1% leaf area affected or less; Nativo 75WG, Tracker and Vivid were most effective (0.3% leaf area affected) (Table 5). The distribution of disease severity within the replicate plots for each treatment is shown in Table 6.

These were all fungicides that gave significant ($p < 0.001$) reductions of white mould in 2012. Folicur, Scala and Switch, fungicides which are primarily known for their activity against *Botrytis* spp., and on narcissus are directed at control of smoulder, did not reduce the level of white mould in 2013 (Table 5). The remaining treatment, Brutus, which gave significant control of both smoulder and white mould in 2012, did not result in a reduced level of white mould in 2013.

These results generally suggest that fungicides which give good control of white mould in a crop one year reduce the risk of early infection on new growth the following year. The most likely explanation for such an effect is that good control of white mould reduces the number of *R. vallisumbrosae* sclerotia (overwintering survival structures) that develop on infected leaves; and hence the quantity of inoculum persisting in crop debris and soil and available to

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infect the new crop. These fungicide treatments may also reduce the ability of sclerotia to germinate.

The lack of a close relationship between levels of white mould in 2012 and 2013 is not surprising given that debris may be blown or moved by machinery between plots; that spores may blow between plots in wind-driven rain, and possibly fungicides may differ in their effect on development and viability of *R. vallisumbrosae* sclerotia. It is noted that Karamate Dry Flo Neotec was less effective than most other fungicides on white mould severity in 2012, yet these plots showed low levels of white mould in 2013. Further work to determine the effect of fungicides on *R. vallisumbrosae* sclerotia formation and their ability to produce viable spores would be required to explain the results of this experiment more clearly.

Table 5. Effect of foliar fungicides applied in 2012 (BOF 072) on narcissus white mould levels in 2013

Fungicide	Mean no. leaves affected (7 Feb)		Mean % leaf area affected	
	Raw data	Log (N^o+1)	15 Feb	27 Feb
1. Untreated	26.8	1.036	1.1	2.5
2. Amistar	7.5	0.808	0.3	**1.1**
3. Brutus	33.2	0.849	1.6	2.1
4. Escolta	3.0	0.520	0.1	**0.6**
5. Folicur	18.5	1.049	1.3	2.3
6. Karamate	5.3	0.714	0.3	**0.6**
7. Nativo	3.5	0.639	0.1	**0.3**
8. Prosaro	13.3	0.850	0.3	**0.8**
9. Scala	70.2	1.640	2.8	4.8
10. Signum	6.8	0.739	0.3	**0.6**
11. Switch	90.8	1.953	4.0	6.0
12. Tracker	3.0	0.564	0.1	**0.3**
13. Vivid	2.5	0.450	0.1	**0.3**
Significance (40 df)	<0.001	<0.001	<0.001	<0.001
LSD vs untreated	34.77	0.5151	1.32	0.91
Between trts	40.15	0.5947	1.53	1.06

Figures in bold are significantly different from the untreated.

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Table 6. Distribution of number of plots in each category at first disease assessment – 7 February 2013

Treatment	Total number plots	Number of plots with leaves affected by white mould in category:			
		Nil	1-10	11-100	>100
1.	8	0	5	2	1
2.	4	0	3	1	0
3.	4	0	3	1	0
4.	4	0	1	2	1
5.	4	1	2	0	1
6.	4	0	4	0	0
7.	4	1	3	0	0
8.	4	1	3	0	0
9.	4	0	3	1	0
10.	4	0	4	0	0
11.	4	0	0	2	2
12.	4	1	2	1	0
13.	4	0	4	0	0

Objective 2 – Effect of foliar fungicides that delay senescence on flower numbers the following year

A small number of flowers developed before 7 February and after 27 February, outside of the period when the field was cropped commercially, and these were not included in the records of flower numbers. Virtually all of the flower buds that developed were marketable. The mean total number of bunches (with 10 flower buds per bunch) picked per plot (8 m length of ridge) ranged from 59.0 to 86.8 (i.e. 74-109 flowers per m length). The number of bunches per plot was significantly increased ($p < 0.001$) by Vivid (73.5), Tracker (76.2) and Signum (86.8) compared with the untreated (60.2) (Table 7). These three fungicides had also resulted in a large increase in % green leaf area when assessed on 11 May 2012 (Table 8). Expressed as a proportion of the flower yield from untreated plots, Signum, Tracker and Vivid increased the number of flower bunches by 44%, 27% and 22% respectively.

Although Amistar, Karamate Dry Flo Neotec and Prosaro also resulted in increased green leaf area on 11 May 2012, they did not increase flower numbers. Possible reasons for this are: the increased photosynthetic activity associated with prolonged green leaf area from

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these products was insufficient to affect number of flower buds the bulb was able to produce; Vivid, Signum and Tracker had an effect on bulb development independent of their leaf greening effect.

The relationship of flower numbers and green leaf area was further examined by simple linear regression analysis. There was a significant association (p = 0.034) of mean number of flower bunches per plot with green leaf area. Green leaf area accounted for 55.3% of the variance in flower numbers.

Table 7. Effect of foliar fungicide treatment in 2012 on yield of marketable narcissus flowers in 2013

Fungicide	Mean number bunches picked				
	7 Feb	9 Feb	12 Feb	15 Feb	Total
1. Untreated	20.5	17.8	15.5	6.5	60.2
2. Karamate	18.8	18.3	15.5	6.5	59.0
3. Amistar	18.8	20.3	**23.0**	8.3	70.2
4. Prosaro	22.5	19.5	**20.5**	7.8	70.2
5. Vivid	16.2	20.0	**29.2**	8.0	**73.5**
6. Signum	17.5	23.3	**35.5**	10.5	**86.8**
7. Tracker	19.5	23.0	**24.0**	9.8	**76.2**
Significance (18 df)	NS	NS	0.003	NS	<0.001
LSD	9.51	4.68	4.56	3.21	10.69

Figures in bold are significantly different from the untreated.

Although the results strongly indicate that prolonging green leaf area increases flower numbers the following year, and previous work has shown that prolonging green leaf area increases bulb yield, it should be borne in mind that it was not possible to relate flower numbers in 2013 to bulb size and density at planting. If these differed greatly along the length of a ridge at planting in 2010, they would probably influence flower yield. To mitigate against this possible confounding factor, flower yield was determined for a relatively long length of ridge (8 m) in each plot, the treatments were replicated four times, and were allocated to plots at random. It was also noted that the assessed lengths of plot were visually quite uniform in density, and there was no evidence of basal rot in the trial area. It seems reasonable to consider therefore that the observed increase in flower yield in 2013 following fungicide treatment in 2012 is a true causal effect.

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Table 8. Effect of fungicides applied in 2012 on narcissus green leaf area in 2012 and marketable flower numbers produced in 2013

Treatment (3 sprays in 2012)	% green leaf area 11 May 2012	Mean number flower bunches picked February 2013
1. Untreated	36.3	60.2
2. Karamate	65.5	59.0
3. Amistar	75.9	70.2
4. Prosaro	94.4	70.2
5. Vivid	94.9	73.5
6. Signum	97.1	86.8
7. Tracker	97.4	76.2
Significance (18 df)	<0.001	<0.001
LSD	10.85	10.69

No fungicides were applied in 2013.

Objective 3 – Examination of crops with rapid dieback symptoms

No fields with symptoms of rapid leaf dieback were observed in crops examined by ADAS staff in Cornwall in May and June 2013. No crops with rapid dieback symptoms were reported from Scotland. One crop (variety unknown) with patches showing dieback symptoms was noted in Surfleet, Lincs and samples were collected on 19 June 2013.

The bulbs were sound with no sign of basal rot or neck rot. Leaf symptoms were yellowing from the leaf tip and pale brown dried dead leaves. On examination in the laboratory the leaves were found to contain one to several oval lesions. No *Botrytis* sclerotia and no sporulation or fruiting bodies of *R. vallisumbrosae* were present. The leaves showing yellowing from the leaf tip contained no lesions.

B. narcissicola was consistently isolated from 9 of the 10 necrotic leaves with pale oval lesions. It is very probable that *B. narcissicola* was the cause of leaf dieback in these plants. No fungal pathogens were isolated from the leaves with yellowing tips.

Objective 4 – Desk study to devise example fungicide programmes for control of foliar diseases

The relative efficacy of fungicides against white mould and smoulder, based on the results of BOF 072 and BOF 072a are summarised in Table 9. BOF 072 identified a wide range of products that greatly reduced development of white mould during the current season's growth; BOF 072a identified products that significantly reduced the disease up to flowering

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in the same crop the following season (i.e. likely due to reduced disease carryover). Results for smoulder are less robust as in only one trial did this disease occur at levels which allowed differentiation of products, and then at relatively low levels. The comparison of product efficacy from BOF 072 is therefore supplemented by a summary of the author's experience of fungicides in controlling Botrytis diseases on protected edible and ornamental crops.

Table 10 summarises the relative cost of fungicides found to be effective on narcissus foliar diseases, and key label conditions of use including maximum number of sprays permitted per crop, and harvest interval, and when the current label/EAMU approval expires.

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Table 9. Relative efficacy of some fungicides against narcissus white mould (*Ramularia vallisumbrosae*) and smoulder (*Botrytis* spp.) based on trials results in BOF 072, BOF 072a and elsewhere

Product	Relative efficacy against white mould		Relative efficacy against *Botrytis* spp.	
	BOF 72	BOF 072a	BOF 72	Other trials
Amistar	***	***	*****	*
Brutus	*****	*	****	NT
Escolta	****	****	***	***
Folicur	*****	*	*****	***
Karamate	***	****	**	NT
Nativo 75WG	****	*****	****	NT
Priori Xtra	***	NT	NT	NT
Prosaro	***	****	*****	NT
Rovral WG	NT	NT	NT	***
Scala	****	*	****	***
Shirlan	*****	NT	NT	***
Signum	*****	****	*****	***
Switch	****	*	*****	****
Tracker	*****	*****	*****	NT
Vivid	*****	*****	****	NT

* 0-20%. ** 21-40%; *** 41-60%; ****61-80%; ***** 81-100% control. NT – not tested.

BOF 072 – calculated from the mean results of 2-5 trials for white mould, 2 for smoulder.

BOF 072a – effect of fungicides one season on white mould at flowering the following season.

Other trials – relative efficacy of those fungicides used against *Botrytis* spp. in other crops.

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Trial 10. Relative cost and some label conditions of fungicides approved and used for control of narcissus leaf diseases (as at August 2013)

Product	Full rate of use (kg or L/ha)	Product cost/ha (1 spray)	Maximum no. sprays	Harvest interval (days)	Label or EAMU	Expires
Amistar	1.0	£29.80	NS (4 L/ha)	NS	0443/09	30 Jun 2024
Bravo 500	2.0	£7.60	1	NS	1130/11	3 Mar 2015
Brutus	3.0	£75.00	3	NS	LTEAU	30 Nov 2019
Escolta	0.35	£23.90	2	35	LTEAU	31 Dec 2021
Folicur	1.0	£16.00	2	28	1516/04	31 Dec 2021
Karamate	2.0	£12.00	4	NS	Label	31 Dec 2018
Nativo 75WG	0.4	£42.90	2	21	LTEAU	31 Dec 2021
Priori Xtra	1.0	£43.00	2	30	LTEAU	31 Dec 2021
Prosaro	1.2	£37.20	3	NS	LTEAU	31 Dec 2021
Rovral WG	1.0	£74.00	4	NS	SOLA 3200/11	30 Apr 2019
Scala	2.0	£66.00	3	3	1315/11	30 Nov 2019
Shirlan	0.4	£12.50	7 (3 L/ha)	NS	LTEAU	31 Dec 2021
Signum	1.35	£64.80	2	NS	2141/12	31 Jul 2019
Switch	1.0	£95.00	3	NS	Label	1 Nov 2014
Tracker	1.5	£31.65	2	NS	LTEAU*	31 Jan 2021
Vivid	1.0	£29.60	2	NS	2884/08	31 May 2014

*Application for an EAMU submitted in July 2013.

NS – not stated

Example spray programmes (Table 11) were devised to comply with label or EAMU conditions of use (e.g. regarding maximum spray number, maximum total dose and harvest interval) and Fungicide Resistance Action committee (FRAC) guidelines to minimise the risk of fungicide resistance (e.g. strobilurin fungicides should make up no more than 50% of sprays in a programme; different fungicide groups are used in alternation).

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Table 11. Example fungicide spray programmes for narcissus leaf diseases

	Pre-flowering spray		Post-flowering sprays				
	1	2	3	4	5	6	7
First-year down, no flowers cropped							
A.	-	Karamate	Signum	Karamate	Tracker	-	-
B.	Karamate	Signum	Folicur	Signum	Folicur	Tracker	-
Second-year down, flowers cropped							
C.	-	Signum	Folicur	Signum	Tracker	-	-
D.	Karamate	Signum	Folicur	Vivid	Tracker	Vivid	-
High *Stagonospora* risk (eg Tazetta varieties/Isles of Scilly), flowers cropped							
E.	-	Signum	Bravo 500	Vivid	Tracker	Vivid	-
F.	Bravo	Signum	Folicur	Vivid	Tracker	Vivid	Tracker

Example 'guideline' programmes A-D are designed for management of white mould and smoulder; programmes E-F for these diseases and leaf scorch. There are numerous other programmes that could be devised using these and/or other fungicides. Varietal susceptibility, disease occurrence in a crop and forecast weather should also be used to inform product choice and spray timing.

The interval between sprays will be determined by interval since last treatment, disease pressure and opportunities to spray. Where early lifting is required, it would be prudent not to apply a late spray of a fungicide that delays leaf dieback.

The above programmes comply with FRAC anti-resistance guidelines for strobilurin fungicides in that these products comprise no more than 50% of spray applications to a crop; and with general anti-resistance strategies of alternating products with actives from different mode of action groups.

Signum is suggested for use pre-flowering because it has a specific off-label approval for use on outdoor ornamentals and no stated harvest interval. Products listed in Table 10 as permitted under the LTAEU will not be permitted when re-registration is completed and the LTAEU expires unless a product subsequently obtains a label or EAMU for use on narcissus/outdoor ornamentals. An application for an EAMU for use of Tracker on narcissus, post-flowering, has been submitted to CRD.

The following points should be borne in mind when devising a spray programme:

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Disease susceptibility

- Grower experience indicates some varieties are more susceptible to smoulder: e.g. Golden Harvest, Tamara, Tamsyn.
- Grower experience indicates some varieties are more susceptible to white mould: e.g. Cheerfulness, Early Flame, Ice Follies.
- The actual disease levels occurring will vary with season, site and crop management.

Crop details

- Both smoulder and white mould tend to increase in severity the longer a crop is down
- Levels of smoulder are generally low in a first-year-down crop, but fungicide treatment around and after flowering can reduce the risk of a high incidence of smoulder primaries the following season
- Severe white mould can occur even in a first-year-down crop, especially in a wet year and where the crop is downwind of other narcissus crops affected by the disease
- Good control of white mould in one year can reduce the risk of severe white mould early in the same crop the following year, by reducing carryover of inoculum

Flower production

- Fungicides that give good control of foliar diseases can delay senescence, resulting in increased bulb yield and increased flower production the following year (e.g. Signum, Tracker, Vivid)

Bulb lifting

- Choice of fungicide product, and timing of the last spray application, in the year of bulb lifting, will be influenced by the need for complete dieback before bulbs are lifted

Spray number

- In crops where three fungicide sprays are applied from immediately after the end of flower harvest, trials in BOF 72 indicated little benefit in applying sprays before flower harvest the exception would be crops where foliar disease is obvious before flower harvest, and areas where there is a history of early foliar disease

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Harvest interval

- Any stated harvest interval on a label applies to the flower harvest as well as the bulb harvest.
- Where there is no stated harvest interval on a label, it can be treated as a zero harvest interval.

Product rate

- In BOF 072 fungicides were each used at their maximum label rate in order to provide a fair evaluation and to check for possible phytotoxicity. It may not be necessary to use products at their maximum label rate for the same beneficial effects.

Control of leaf scorch (Stagonospora curtisii)

Following the Daffodil Growers Association meeting in Cornwall on 22 May 2013, and discussions with growers from the Isles of Scilly at this meeting, it was requested that information on fungicide options for control of leaf scorch should be examined.

No replicated trials evaluating fungicides for control of leaf scotch have been conducted in the UK for many years. The disease did not occur in any of the trials in BOF 072 or BOF 072a. Fungicide options for control of leaf scotch *Stagonospora curtisii* on narcissus were therefore investigated by reference to *Stagonospora norodum* on wheat. In the last detailed work done on this wheat disease in the UK, around 10 years ago (Lockley & Clarke, 2005), good control was given by:

- Amistar (azoxystrobin)
- Twist (trifloxystrobin)
- Vivid (pyraclostrobin)

Vivid at half dose gave control equivalent to or better than a full dose of most other fungicides tested.

In later work on wheat, azole/strobilurin mixtures (Fandango [fluoxystrobin + prothioconazole] and Swing Gold [dimoxystrobin + epoxiconazole]) showed a small improvement over the corresponding azole.

Bravo 500 was a reasonable protectant.

The azole/strobilurin mixtures used on narcissus in BOF 72 were:

- Priori Extra (azoxystrobin + cyproconazole)

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- Escolta (cyproconazole + trifloxystrobin)
- Nativo 75 WG (tebuconazole + trifloxystrobin)

The latter two were very good on white mould in our trials with no observed phytotoxic effects and warrant testing for control of leaf scorch.

Work in Lithuania in 2003 and 2004 reported that both triazole and strobilurin fungicides significantly suppressed epidemic progress of *Stagonospora nodorum* on wheat (Gaurilcikiene & Ronis, 2006). Effective ingredients included azoxystrobin (e.g. Amistar), epoxiconazole (e.g. Epic) and pyraclostrobin + epoxiconazole (e.g. Opera); the latter treatment was the most effective.

Based on these results, an example programme for control of narcissus leaf diseases in areas / crops where there is a high risk of leaf scorch is given in Table 11 (above).

Conclusions

1. The severity of white mould at flower harvest of cv. Early Flame in Cornwall in February 2013 was significantly reduced (p <0.001) by eight fungicides applied as post-flowering sprays (3 applications) the previous year; Nativo 75WG, Tracker and Vivid were most effective. It is suggested that these treatments reduced the quantity of viable inoculum of *R. vallisumbrosae* persisting to February 2013.
2. Occurrence of narcissus smoulder is unpredictable. Following a low level of smoulder (c. 2% leaf area affected) on cv. Early Flame in April 2012, no smoulder primaries were recorded in the crop between emergence and the end of flower picking in 2013.
3. *B. narcissicola* was the cause of leaf dieback in a sample that showed rapid dieback symptoms in 2013.
4. Increased green leaf area in May 2012 resulting from foliar fungicide treatment significantly (p = 0.034) increased the flower yield of narcissus cv. Early Flame in February 2013.
5. Signum, Tracker and Vivid had the greatest effect on flower yield, increasing the number of marketable bunches by 44%, 27% and 22% respectively.

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Lockley D & Clark WS (2005). Fungicide dose-response trials in wheat: the basis for choosing ‘appropriate dose’. HGCA Project Report 373.

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Technology transfer

Presentation

O’Neill TM (2013). Fungicides for improved control of white mould and smoulder. HDC/British Daffodil Growers Association Technical Seminar, Redruth, Cornwall, 22 May 2013.

Article

O’Neill TM (2013). Protect the leaves, protect your yield. *HDC News* **197**(in press).

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Appendix 1 – Crop diary

Date	Action
2011	
30 Nov	Trial marked out
2012	
5 Jan	Crop at 90% emergence
13 Feb	First flower pick
16 Feb	Spray 1
1 Mar	Spray 2
20 Mar	Spray 3
11 May	Assessed green leaf area
2013	
8 Jan	Trial re-marked
15 Jan	Crop at 100% emergence, shoots 7.5 – 15 cm
28 Jan	Leaves 15 cm, buds 2 cm. No smoulder or white mould present
7 Feb	Flowers picked. Disease assessment
9 Feb	Flowers picked
12 Feb	Flowers picked
15 Feb	Flowers picked
15 Feb	Disease assessment
27 Feb	Disease assessment

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