SCEPTREPLUS

Final Trial Report

Trial code:	CP 205 WP16
Title:	Narcissus bulb treatments for Fusarium control
Crop	*Narcissus*
Target	*Fusarium oxysporum* f.sp. *narcissi*
Lead researcher:	Dr John Clarkson
Organisation:	Warwick Crop Centre, School of Life Sciences, University of Warwick
Period:	Aug 2022 – June 2023
Report date:	May 2023
Report author:	John Clarkson
ORETO Number:	Under renewal

I the undersigned, hereby declare that the work was performed according to the procedures herein described and that this report is an accurate and faithful record of the results obtained.

23/05/2023 John Clarkson

Date Authors signature

Trial Summary

Introduction

The soilborne fungal plant pathogen *F. oxysporum* f.sp. *narcissi* (FON) is a major problem for the UK Narcissus industry, causing a severe basal rot of bulbs. Approval for the fungicides thiabendazole (Storite) and chlorothalonil (Bravo) used for many years in hot water treatment (HWT) of bulbs has now been withdrawn and an EAMU for an alternative effective fungicide prochloraz was rejected by CRD. Narcissus growers are therefore now faced with potential extensive losses due to Fusarium basal rot in the absence of any control measures for FON. In response to the AHDB SCEPTRE+ call, this project aims to identify chemical or biological crop protection products that can potentially reduce basal rot in Narcissus when applied in furrow in the field rather than in HWT using an established pot-based glasshouse trial. Application of crop protection products in the field rather than in HWT may be more conducive to gaining approvals. The glasshouse pot trial uses an artificial inoculation approach project developed and utilised previously to identify effective fungicides for FON control in AHDB projects BOF 74a and SCEPTRE+ CP45.

Methods

Seven crop protection products comprising five chemical fungicides and two microbial biological control agents were evaluated for their efficacy in controlling Fusarium basal rot caused by FON. Disease-free *Narcissus* bulbs (cv. Golden Harvest) were treated with each product either by direct spraying onto bulbs in pots 'in-furrow' or in a small-scale HWT system (product AHDB9719 only at three different rates) before planting into compost infested with FON. Control treatments were also set up consisting of in-furrow and HWT bulbs without any crop protection treatments planted in FON infested compost. Additional untreated bulbs were also planted into non-inoculated compost. After one cycle of flower production, *Narcissus* bulbs were bisected and assessed for Fusarium basal rot incidence (percentage bulbs affected) and severity based on the area of each bulb affected using a 0-10 scoring scale (where 0 = no infection and 10 = whole bulb rotted). Crop safety was also assessed by recording bulb germination and any treatment effects on foliage.

Results

AHDB9719, AHDB9741 and AHDB9718 when applied in-furrow resulted in the lowest disease incidence with 30%, 40% and 45% of bulbs affected respectively, compared to 57.5% in the corresponding inoculated untreated bulbs (Table A). The same treatments also resulted in a greater percentage of bulbs in the low disease category (77.5, 72.5 and 70.0% of bulbs respectively) compared with the untreated bulbs (60% of bulbs).

AHDB9719 was also effective at reducing FON incidence when applied at different concentrations in HWT, with FON incidence of 47.5%, 37.5% and 42.5% for concentrations equivalent to 0.4, 0.8 and 1.2 L ha^{-1} respectively compared with 72.5% in the HWT untreated bulbs. The same treatments also had a greater percentage of bulbs in the low disease severity category (67.5%, 75.0% and 87.5% of bulbs respectively) compared with the untreated HWT bulbs (45.0% of bulbs).

Treatment of bulbs with AHDB9719, AHDB9741 and AHDB9718 in-furrow also reduced mean basal rot severity (mean disease scores 1.75, 2.00, and 2.38 respectively) compared with the untreated inoculated control (mean disease score 3.18) but this was not statistically significant. All concentrations of AHDB9719 applied as a HWT also reduced mean basal rot severity (mean disease scores 2.15, 1.80 and 1.18 for 0.4, 0.8 and 1.2 L ha^{-1} respectively) compared with the untreated inoculated HWT bulbs (mean disease score 5.05) but this was only significant ($p>0.05$) for the highest two concentrations (Table A).

Table A. Effect of crop protection products applied either in-furrow or in hot water treatments (HWT) on Fusarium basal rot incidence (%FON), percentage of bulbs with low, medium and high disease severity scores and overall mean severity score for *Narcissus* bulbs planted in compost inoculated with FON. Data are means for 40 bulbs per treatment.

		Treatment[1]	FRAC code	% FON[2]	% low severity[3]	% medium severity[3]	% high severity[3]	Mean basal rot severity[4]	SEM
1	In-furrow treatments	AHDB9816	E2	45.0	60.0	5.0	35.0	3.05	0.702
2		AHDB9717	C2	60.0	57.5	7.5	35.0	2.98	0.709
3		AHDB9725[B]	BM02	52.5	65.0	2.5	32.5	2.88	0.533
4		AHDB9719	G1	30.0	77.5	0.0	22.5	1.75	0.526
5		AHDB9741	B1	40.0	72.5	7.5	20.0	2.00	0.466
6		AHDB9726[B]	BM02	50.0	60.0	2.5	37.5	2.95	0.302
7		AHDB9718	C2	45.0	70.0	2.5	27.5	2.38	0.792
8	HWT treatments	AHDB9719 0.4 L/ha	G1	47.5	67.5	10.0	22.5	2.15	0.625
9		AHDB9719 0.8 L/ha	G1	37.5	75.0	7.5	17.5	1.80	0.450
10		AHDB9719 1.2 L/ha	G1	42.5	87.5	0.0	12.5	1.18	0.355
11	Control for in-furrow treatments	Untreated bulbs in FON infested compost		57.5	60.0	7.5	32.5	3.18	0.476
12	Control for HWT treatments	Untreated HWT bulbs in FON infested compost		72.5	45.0	0.0	55.0	5.05	0.665
13	Uninoculated Control	Untreated bulbs in uninoculated compost		22.5	97.5	0.0	2.5	0.38	0.158

[B] indicates microbial biological control agent.
[1] In-furrow = treatments applied to bulbs *in situ* in FON infested compost before covering with further compost; HWT = treatments applied during hot water treatment then planted into FON infested compost; Controls = untreated in-furrow (water treatment in furrow, FON infested compost), untreated HWT (no treatment added to hot water, FON infested compost), uninoculated compost (no treatment, no FON).
[2] Mean percentage of *Narcissus* bulbs affected with basal rot.
[3] Mean percentage of *Narcissus* bulbs in different disease severity categories. Disease severity based on area of *Narcissus* bulb affected with basal rot using a 0-10 scale where 0 = no infection and 10 = whole bulb rotted. Low severity = 0-2; medium severity = 3-5; high severity = 6-10.
[4] Green shading indicates products applied in HWT with a significant reduction in mean basal rot severity score ($p < 0.05$) compared to the untreated HWT inoculated control. No products applied in furrow significantly reduced basal rot compared with the untreated control.
SEM = standard error of the mean.

Conclusions

Three chemical fungicides AHDB9719, AHDB9741 and AHDB9718 resulted in some control of Fusarium basal rot of *Narcissus* when applied in-furrow. AHDB9719 also resulted in significant control when used in HWT. AHDB9741 is currently approved for post-harvest use on potatoes but FON isolates resistant or tolerant to the active have been identified previously (AHDB project BOF74). AHDB9719 offers alternative chemistry for control of FON when applied in furrow and as HWT and could be used as part of an effective fungicide resistance management programme. A field experiment testing the same products is also being carried out by Hutchinson's and results will be presented at an industry event in due course.

Take home message

The fungicides AHDB9719, AHDB9741 and AHDB9718 resulted in a reduction in Fusarium basal rot of *Narcissus* and therefore provide a new opportunity for disease management.

Objective

1. To determine the effect of crop protection products (chemical fungicides and microbial biological control agents) applied as in-furrow treatments on subsequent development of Fusarium basal rot in *Narcissus.*

2. To determine the effect of a single fungicide applied at different concentrations in HWT on subsequent development of Fusarium basal rot in *Narcissus.*

Trial conduct

UK regulatory guidelines were followed but EPPO guidelines took precedence. The following EPPO guidelines were followed:

Relevant EPPO guideline(s)		**Variation from EPPO**
PP 1/152(3)	Design and analysis of efficacy evaluation trials	None
PP 1/135(3)	Phytotoxicity assessment	None
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including GEP	None

There were no deviations from EPPO guidance.

Test site

Item	**Details**
Location address	University of Warwick Wellesbourne Campus Wellesbourne Warwick CV35 9EF
Crop	*Narcissus*
Cultivar	Carlton
Soil or substrate type	Specialist compost
Agronomic practice	N/A
Prior history of site	N/A

Trial design

Item	**Details**
Trial design:	Randomised block
Number of replicates:	Eight replicate pots of five *Narcissus* bulbs in eight blocks (N=40 bulbs per treatment)
Row spacing:	N/A
Plot size: (w x l)	N/A
Plot size: (m^2)	N/A
Number of plants per plot:	N/A

Treatment details

	AHDB code[1]	Active substance	Product name/ manufacturers code	FRAC code	Formulation batch number	Content of active substance in product	Formulation type	Adjuvant
1	AHDB9816	NA	NA	E2		NA	Water dispersible granule	
2	AHDB9717	NA	NA	C2		NA	Suspension concentrate	
3	AHDB9725[B]	NA	NA	BM02		NA	Wettable powder	
4	AHDB9719	NA	NA	G1		NA	Suspension concentrate	Agral 0.09%[1]
5	AHDB9741	NA	NA	B1		NA	Suspension concentrate	
6	AHDB9726[B]	NA	NA	BM02		NA	Wettable powder	
7	AHDB9718	NA	NA	C2		NA	Suspension concentrate	

[B] indicates microbial biological control agent.

Application schedule

Treatment number	Treatment: product name or AHDB code	Rate of active substance (g a.s./ha)	Rate of product (l or kg/ha)	Application code
1	AHDB9816	NA	NA	B
2	AHDB9717	NA	NA	B
3	AHDB9725[B]	NA	NA	B
4	AHDB9719	NA	NA	B
5	AHDB9741	NA	NA	B
6	AHDB9726[B]	NA	NA	B
7	AHDB9718	NA	NA	B
		Rate of active substance (g a.s. L^{-1} in HWT)	**Rate of product (ml L^{-1} in HWT)**	
8	AHDB9719	NA	NA	A
9	AHDB9719	NA	NA	A
10	AHDB9719	NA	NA	A

Application details

	Application A (Hot water treatment)	Application B (In furrow treatment)
Application date	09/08/22	11/08/22
Time of day	11.00	11.00
Crop growth stage (Max, min average BBCH)	n/a	n/a
Crop height (cm)	n/a	n/a
Crop coverage (%)	n/a	n/a
Application Method	Hot water dip	Spray
Application Placement	Bulb	
Application equipment	Water tank	Berthoud Vermorel 2000HP
Nozzle pressure	n/a	2 bar
Nozzle type	n/a	05F110
Nozzle size	n/a	05
Application water volume/ha	n/a	1000
Temperature of air - shade (°C)		20
Relative humidity (%)	n/a	n/a
Wind speed range (m/s)	n/a	n/a
Dew presence (Y/N)	n/a	n/a
Temperature of soil - 2-5 cm (°C)	n/a	n/a
Wetness of soil - 2-5 cm	n/a	n/a
Cloud cover (%)	n/a	n/a

Experimental setup and application details

Summary of approach

Seven crop protection products comprising five chemical fungicides and two microbial biological control agents as listed above were evaluated for their efficacy in controlling Fusarium basal rot caused by *F. oxysporum* f.sp. *narcissi* (FON). All products were applied to disease-free *Narcissus* bulbs (cv. Golden Harvest) as an in-furrow treatment (over the bulbs after placing in pots). In addition, one fungicide (AHDB9719) was applied as part of a small-scale hot water treatment (HWT; as routinely used by the industry both to apply fungicides and control stem nematode) at three concentrations. *Narcissus* bulbs were planted into compost infested with FON and after one cycle of flower production, assessed for basal rot. Crop safety was also assessed by recording bulb germination and any effects on foliage.

Application of crop protection products in HWT

Four 38 L water baths were filled with 35 L of water with the addition of 3 mL of Agral (a non-ionic wetting agent) and allowed to reach the standard working HWT temperature of 44.4°C. Each product under test was allocated a bath with one bath used exclusively for all the untreated control bulbs. When the baths had reached the working temperature, the appropriate amount of the test product was added and mixed briefly. Fusarium-free *Narcissus* bulbs (cv. Golden Harvest) contained in nets were then lowered gently into the water baths, and a wire mesh placed on top to ensure the complete immersion of the bulbs during treatment. The baths were allowed to reach the working temperature of 44.4°C before commencing timing of the standard 3.25 hours HWT. At the end of the treatment, the bulb nets were immediately removed from the baths and the excess water drained. Nets were then placed into slatted trays and the bulbs dried at ambient temperature for 48 hours before use. Lots of 40 *Narcissus* bulbs for the experiment were treated on 09/08/22 (2 days before planting).

Application of crop protection products in-furrow (over bulbs after planting)

Eight pots with 5 untreated bulbs for each treatment were placed on an initial layer of FON infested compost (see below) and arranged within a 2.6 m line. Treatments were applied using a knapsack sprayer fitted with one 05F110 nozzle (to give a 0.5m swath width) in a volume equivalent to 1000 L spray solution per hectare. Treatments were allowed to dry before the bulbs were covered with further FON infested compost.

FON inoculum

FON isolate FON139 previously identified as being highly pathogenic on *Narcissus* (AHDB Project BOF 74) was grown on potato dextrose agar for approx. five days at 20°C to produce actively growing cultures. Agar plugs from the leading edge of the colonies were then used to inoculate a sterile mix of M2 compost and wheat bran in 1 L flasks which were incubated at 25°C in the dark for approx. four weeks. To quantify the inoculum, the number of FON colony forming units (cfu) were enumerated by series dilution.

Bulb planting and inoculation

Narcissus bulbs treated with the different crop protection products (either in furrow or through HWT) were planted in 20 cm diameter, 4 L capacity plastic plant-pots in a specialised growing medium consisting of a blend of sphagnum peat / horticultural sand (3:1, v/v) mixed with John Innes No.1 compost (1:1, v/v) and amended with ammonium nitrate (0.40 kg m^{-3}), potassium nitrate (0.75 kg m^{-3}), single super-phosphate (1.50 kg m^{-3}), ground chalk (2.25 kg m^{-3}), ground magnesian limestone (2.25 kg m^{-3}) and fritted trace elements WM 255 (0.40 kg m^{-3}). The growing medium was artificially inoculated with appropriate amounts of FON inoculum to give a final level of 1 x 10^5 cfu g^{-1}. Five *Narcissus* bulbs were then planted approx. 10 cm deep (measured to the

base of the bulb) in each pot. HWT treated bulbs were treated before planting, whereas in-furrow treatments were applied to untreated bulbs when first placed in the pots but before being covered by further FON infested compost. Control treatments were also set up consisting of HWT bulbs and in-furrow treated bulbs without any crop protection treatments planted in the growing medium inoculated with FON. In addition, untreated bulbs were also placed in uninoculated compost to observe background levels of Fusarium in any of the bulbs. Pots were placed in saucers and watered until the compost was damp. They were placed at approx. 5˚C in the dark for 13 weeks before being moved to a glasshouse at 15˚C and with a 16hr photoperiod for 15 weeks to force flowering. In total there were eight replicate pots of five bulbs (total 40 bulbs) per treatment which were randomised in eight blocks across two benches in the glasshouse compartment (see Appendix).

Plant and bulb assessments

To assess crop safety, *Narcissus* plants were assessed on five occasions for bulb emergence and mottling or chlorosis of foliage which might indicate phytotoxicity. When most plants had begun to senesce, watering was halted 9 weeks after being moved to the glasshouse and all the pots allowed to dry out for approx. six weeks before the bulbs were harvested and assessed for Fusarium basal rot. This was achieved by bisecting the bulbs lengthways and recording disease area based on a 0-10 scoring scale where 0 = no infection and 10 = whole bulb affected (Table 1).

Data summaries and analyses

Crop safety: Mean percentage of germinated *Narcissus* bulbs and the mean number of leaves showing chlorosis were calculated for each treatment.

Basal rot disease: Overall incidence of Fusarium basal rot was calculated as the mean percentage of bulbs for each treatment that had a severity score >1 (%FON). The mean percentage of *Narcissus* bulbs with low (score 0-2), medium (score 3-5) and high disease severity (score 6-10) (Table 1) was also calculated. Finally, mean basal rot severity score (over all bulbs in each treatment) was calculated for each treatment and ANOVA* carried out followed by post-hoc pairwise Tukey's tests to identify treatments that reduced the mean basal rot disease score compared to the in-furrow and HWT bulbs that received no crop protection products (HWT untreated inoculated control).

* Note: datasets analysed by ANOVA were not normally distributed, therefore a log transformation was applied

Table 1. Scoring scale for assessing the severity of Fusarium basal rot in *Narcissus* bulbs.

Score[1]	Severity	Zones affected by basal rot
0	Low	None
1	Low	Spot or spots (up to 2mm-diameter) in base plate
2	Low	Small area of basal plate (up to 10%) but no spread to bulb scales
3	Medium	Up to 25% of basal plate area but no spread to bulb scales
4	Medium	Up to 50% of basal plate area but no spread to bulb scales
5	Medium	More than 50% of basal plate area but no spread to bulb scales
6	High	Start of spread from basal plate to bulb scales (up to 10% of scale area)
7	High	Up to 25% of bulb scale area
8	High	Up to 50% of bulb scale area
9	High	More than 50% of bulb scale area
10	High	Whole bulb (or virtually whole bulb) (includes dried, 'mummified' bulbs)

[1] Disease scores of 1-5 relate to basal rot in the base plate only; scores 6-10 relate to rot in bulb scales and are irrespective of percentage of basal plate affected.

Untreated levels of pests/pathogens at application and through the assessment period

Common name	Scientific Name	EPPO Code	Infestation level pre-application	Infestation level at start of assessment period	Infestation level at end of assessment period
Fusarium	*Fusarium oxysporum* f.sp. *narcissi*	N/A	N/A	N/A	HWT untreated inoculated control 72.5% basal rot incidence and mean disease score of 5.1 (max 10) In-furrow untreated inoculated control bulbs 57.5% basal rot incidence and mean disease score of 3.2 (max 10)

Assessment details

	Evaluation Timing (DA)*				
Evaluation date	After conventional fungicides	After Bio-fungicides	Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotox)	Assessment
02.12.22	113	113	N/A	Phytotoxicity	Emergence/Foliage
12.12.22	123	123	N/A	Phytotoxicity	Emergence/Foliage
20.12.22	131	131	N/A	Phytotoxicity	Emergence/Foliage
03.01.23	145	145	N/A	Phytotoxicity	Emergence/Foliage
09.01.23	151	151	N/A	Phytotoxicity	Emergence/Foliage
24.02.23	197	197	N/A	Disease	Basal rot

Results

Phytotoxicity

There was little effect of any of the treatments on bulb emergence, with all treatments resulting in ≥95% emergence at the last assessment time on 09/01/23 (Table 2). However, bulbs which received a HWT regardless of the addition of a crop protection product emerged significantly earlier than those without HWT, with ≥92.5% emergence of HWT bulbs by 02/12/23. In-furrow treated (and uninoculated) bulbs emerged slower with 25-70% emergence on 02/12/23 and only reached ≥95% emergence by 03/01/23 across all treatments.

There was little evidence of mottling or chlorosis of *Narcissus* leaves from treated bulbs (1.1-5.6 leaves affected, Table 2). Control treatments (untreated HWT and in-furrow, and uninoculated with FON) also had some of these symptoms with untreated HWT bulbs having the most chlorosis at 10.6%. Leaf mottling can often be due to the HWT while chlorosis has been associated with Fusarium infection (AHDB Project BOF 74a) so this may have confounded results. However there did not appear to be any major issues with crop safety.

Table 2. Effect of crop protection products on emergence and leaf chlorosis of *Narcissus* bulbs

Application method	Treatment	Mean % bulb emergence	Mean no. leaves wilted/yellow[2]	SEM
In-furrow	AHDB9816	95	3.25	1.49
	AHDB9717	97.5	2.00	0.65
	AHDB9725[B]	97.5	1.88	0.72
	AHDB9719	100	2.38	1.02
	AHDB9741	97.5	2.38	1.22
	AHDB9726[B]	100	3.88	1.06
	AHDB9718	100	3.25	1.66
HWT	AHDB9719 0.4 L/ha	100	5.63	1.99
	AHDB9719 0.8 L/ha	100	4.88	0.88
	AHDB9719 1.2 L/ha	100	1.13	0.61
Controls	Untreated In Furrow	97.5	3.13	1.08
	Untreated HWT	97.5	10.63	1.52
	Uninoculated compost	100	0.88	0.40

[B] indicates microbial biological control agent.

Efficacy

Fusarium basal rot disease incidence and percentage of bulbs with different disease severity

There were clear differences in the incidence of FON basal rot between untreated bulbs planted directly as a control for in-furrow treatments and those that had undergone HWT, with more disease developing in the untreated HWT bulbs (72.5%) than non-HWT bulbs (57.5%). This was consistent with previous reports where HWT was shown to promote Fusarium basal rot in apparently healthy asymptomless bulbs in the absence of fungicides (AHDB BOF 74a).

Crop protection products applied as an in-furrow treatment varied in their efficacy in reducing Fusarium basal rot resulting in FON incidence levels varying between 30 and 60% (Table 3). AHDB9719, AHDB9741 and AHDB9718 when applied in-furrow resulted in the lowest disease incidence with 30%, 40% and 45% of bulbs affected respectively, compared to AHDB9717 which resulted in 60% FON incidence (Table 3). These same treatments also resulted in fewer bulbs with medium or severe disease, with a greater percentage of bulbs in the low disease category

(77.5, 72.5 and 70.0% of bulbs respectively; scores 0-2) compared with untreated control bulbs (60% of bulbs with scores 0-2). AHDB9719 was also effective at reducing FON incidence when applied at different concentrations in HWT, with FON incidence of 47.5%, 37.5% and 42.5% for concentrations equivalent to 0.4, 0.8 and 1.2 L ha^{-1} respectively compared with 72.5% in the HWT untreated bulbs (Table 3). The same treatments also had a greater percentage of bulbs in the low disease severity category (67.5%, 75.0% and 87.5% of bulbs; scores 0-2) compared with the untreated HWT bulbs (45.0% of bulbs with scores 0-2).

Disease severity

Treatment of bulbs with AHDB9719, AHDB9741 and AHDB9718 in-furrow also reduced mean basal rot severity (mean severity scores 1.75, 2.00, and 2.38 respectively) compared with the untreated inoculated control (mean severity score 3.18) but this was not statistically significant. All concentrations of AHDB9719 applied as a HWT also reduced mean basal rot severity (mean severity scores 2.15, 1.80 and 1.18 for 0.4, 0.8 and 1.2 L ha^{-1} respectively) compared with the untreated inoculated HWT bulbs (mean severity score 5.05) but this was only significant ($p>0.05$) for the highest two concentrations (Table 3, Figure 1).

Table 3. Effect of crop protection products applied either in-furrow or in hot water treatments (HWT) on Fusarium basal rot incidence (%FON), percentage of bulbs with low, medium and high disease severity scores and overall mean severity score for *Narcissus* bulbs planted in compost inoculated with FON. Data are means for 40 bulbs per treatment.

	Application method[1]	Treatment	% FON[2]	% bulbs low severity[3]				% bulbs medium severity[3]				% bulbs high severity[3]						Mean basal rot score[4]	SEM
				0	1	2	Total	3	4	5	Total	6	7	8	9	10	Total		
1	In-furrow	AHDB9816	45.0	55.0	2.5	2.5	**60.0**	0.0	2.5	2.5	**5.0**	5.0	15.0	5.0	0.0	10.0	**35.0**	3.05	0.60
2		AHDB9717	60.0	40.0	17.5	0.0	**57.5**	5.0	0.0	2.5	**7.5**	10.0	17.5	0.0	5.0	2.5	**35.0**	2.98	0.53
3		AHDB9725[B]	52.5	47.5	12.5	5.0	**65.0**	0.0	0.0	2.5	**2.5**	12.5	0.0	10.0	2.5	7.5	**32.5**	2.88	0.58
4		AHDB9719	30.0	70.0	5.0	2.5	**77.5**	0.0	0.0	0.0	**0.0**	7.5	7.5	0.0	7.5	0.0	**22.5**	1.75	0.49
5		AHDB9741	40.0	60.0	7.5	5.0	**72.5**	5.0	0.0	2.5	**7.5**	2.5	7.5	5.0	2.5	2.5	**20.0**	2.00	0.50
6		AHDB9726[B]	50.0	50.0	7.5	2.5	**60.0**	0.0	2.5	0.0	**2.5**	12.5	10.0	7.5	7.5	0.0	**37.5**	2.95	0.56
7		AHDB9718	45.0	55.0	12.5	2.5	**70.0**	0.0	2.5	0.0	**2.5**	10.0	2.5	5.0	7.5	2.5	**27.5**	2.38	0.55
8	HWT	AHDB9719 0.4 L/ha	47.5	52.5	7.5	7.5	**67.5**	7.5	2.5	0.0	**10.0**	5.0	12.5	2.5	2.5	0.0	**22.5**	2.15	0.46
9		AHDB9719 0.8 L/ha	37.5	62.5	12.5	0.0	**75.0**	2.5	2.5	2.5	**7.5**	2.5	5.0	2.5	7.5	0.0	**17.5**	1.80	0.48
10		AHDB9719 1.2 L/ha	42.5	57.5	30.0	0.0	**87.5**	0.0	0.0	0.0	**0.0**	5.0	2.5	5.0	0.0	0.0	**12.5**	1.18	0.36
11	Controls	Inoculated untreated in-furrow	57.5	42.5	17.5	0.0	**60.0**	5.0	0.0	2.5	**7.5**	7.5	2.5	0.0	15.0	7.5	**32.5**	3.18	0.61
12		Inoculated untreated HWT	72.5	27.5	7.5	10.0	**45.0**	0.0	0.0	0.0	**0.0**	5.0	10.0	2.5	17.5	20.0	**55.0**	5.05	0.67
13		Uninoculated compost	22.5	77.5	17.5	2.5	**97.5**	0.0	0.0	0.0	**0.0**	2.5	0.0	0.0	0.0	0.0	**2.5**	0.38	0.16

[B] indicates microbial biological control agent.

[1] In-furrow = treatments applied to bulbs *in situ* in FON infested compost before covering with further compost; HWT = treatments applied during hot water treatment then planted into FON infested compost; Controls = untreated in-furrow (water treatment in furrow, FON infested compost), untreated HWT (no treatment added to hot water, FON infested compost), uninoculated compost (no treatment, no FON).

[2] Mean percentage of *Narcissus* bulbs affected with basal rot.

[3] Mean percentage of *Narcissus* bulbs in different disease severity categories. Disease severity based on area of *Narcissus* bulb affected with basal rot using a 0-10 scale where 0 = no infection and 10 = whole bulb rotted. Low severity = 0-2; medium severity = 3-5; high severity = 6-10.

[4] Green shading indicates products applied in HWT with a significant reduction in mean basal rot severity score ($p < 0.05$) compared to the untreated HWT inoculated control. No products applied in furrow significantly reduced basal rot compared with the untreated control.

SEM = standard error of the mean.

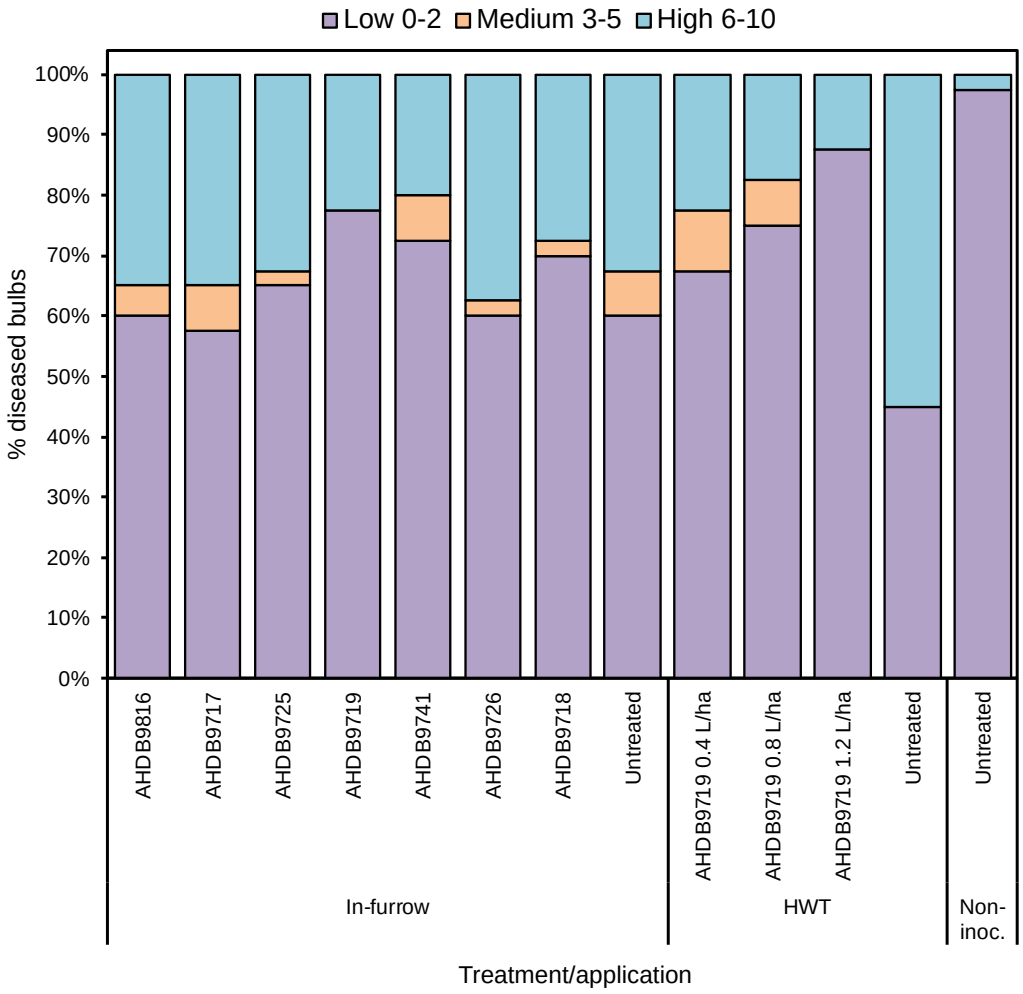

Figure 1. Effect of crop protection products applied either in-furrow or in hot water treatments (HWT) on percentage of *Narcissus* bulbs in different Fusarium basal rot disease severity categories after planting in compost inoculated with FON. Data are means for 40 plants per treatment. Data for products should be compared with either the untreated HWT or in furrow-inoculated controls as appropriate.

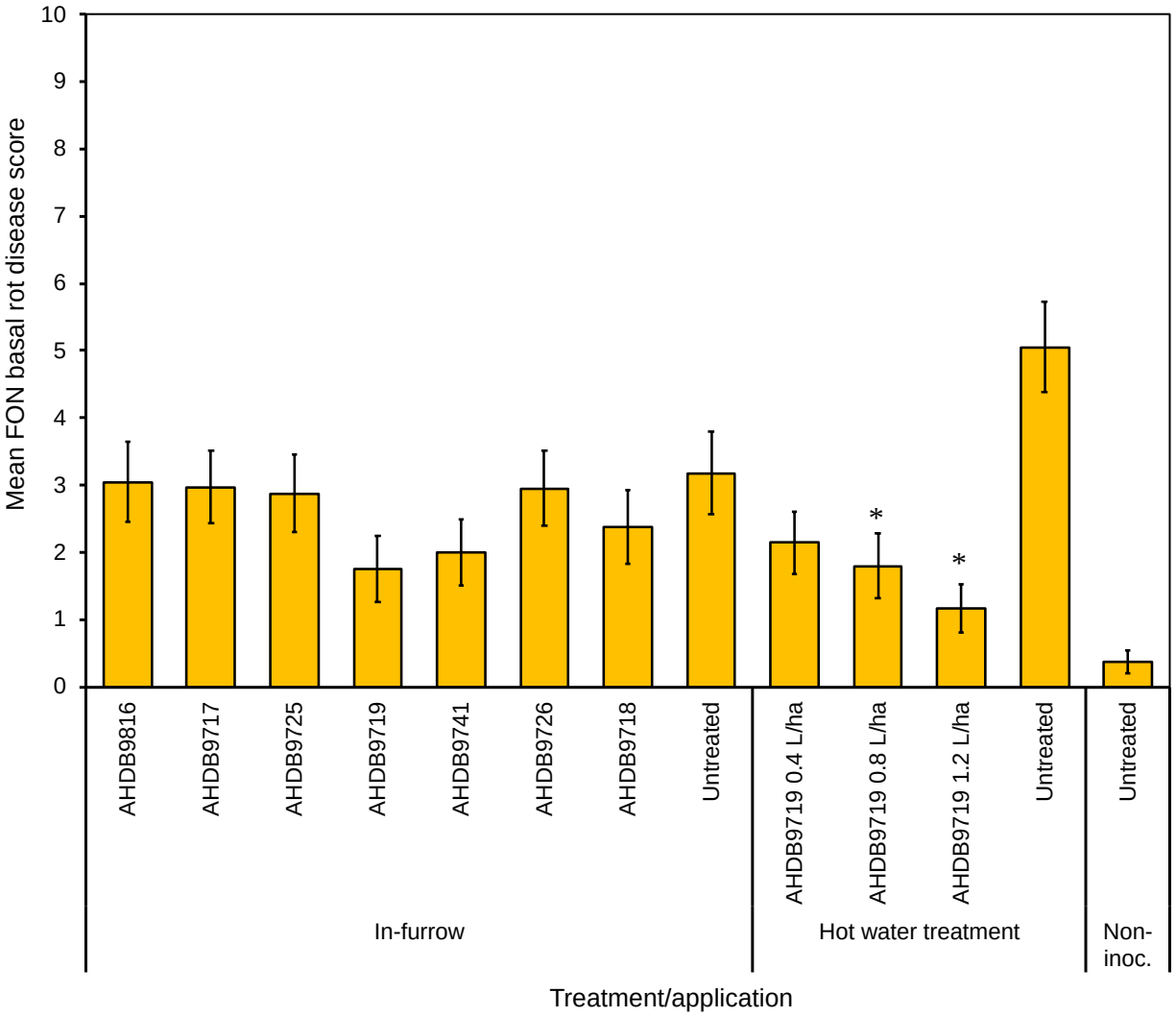

Figure 2. Effect of crop protection products applied either in-furrow or in hot water treatments (HWT) on mean Fusarium basal rot disease severity score after planting in compost inoculated with FON. Data are means for 40 plants per treatment. Asterisks indicate products applied in HWT with a significant reduction in basal rot ($p < 0.05$) compared with the untreated HWT control. No products applied in furrow significantly reduced basal rot compared with the untreated control.

Discussion

A FON-inoculated pot-based glasshouse bioassay was successful in establishing high levels of Fusarium basal rot in *Narcissus* bulbs allowing the efficacy of different crop protection products for control to be successfully evaluated. Both conventional chemical fungicides and microbial biological control agents were tested as in-furrow treatments and one chemical fungicide was tested as part of HWT at different concentrations. None of the products had phytotoxic effects and therefore could be considered as crop safe.

Three chemical fungicides AHDB9719, AHDB9741 and AHDB9718 resulted in some control of Fusarium basal rot of *Narcissus* when applied as an in-furrow treatment. AHDB9719 was also effective at significantly reducing basal rot when applied as a HWT at three different concentrations, with the highest dose being the most effective. AHDB9741 is approved for post-harvest use on potatoes (FRAC code B1), but FON isolates resistant or tolerant to this active have been identified previously (AHDB project BOF74). AHDB9719 (FRAC code G1;) applied either in-furrow or in HWT and AHDB9718 (FRAC code C2) applied in-furrow therefore offer

alternative chemistry for some control of FON and if approved, these products could be used as part of an effective fungicide resistance management programme.

It has been shown previously that in the absence of fungicides, HWT can promote Fusarium basal rot development in seemingly clean bulb stocks which may carry a background level of FON inoculum or could impose a stress which could pre-dispose the bulb to infection once planted in infested soil (AHDB Project BOF 74a). The use of fungicides in HWT also serves to prevent spread of FON spores from infected to clean bulbs. Therefore, the use of fungicides in HWT is very important to prevent an increase in basal rot in Narcissus bulbs before planting. AHDB9719 was shown to be effective in HWT at reducing FON incidence compared to untreated HWT bulbs and therefore is a good candidate fungicide .

If bulbs do not undergo HWT, then the three products AHDB9719, AHDB9741 and AHDB9718 offer potential to reduce basal rot in the field.

Finally, a field experiment testing the same products is also being carried out by Hutchinson's and results will be presented at an industry event in due course.

Conclusions

- AHDB9719, AHDB9741 and AHDB9718 resulted in some control of Fusarium basal rot of *Narcissus* when applied as an in-furrow treatment. AHDB9719 was also very effective when applied as a HWT.
- An integrated programme for control of basal rot based on these products is necessary to minimise risk of resistance.

Acknowledgements

We gratefully acknowledge Mark Clark at Grampian Growers for supplying the Narcissus bulbs, funding from AHDB and industry for this work through the AHDB Sceptre+ project as well as the help and advice of all the manufacturers who supplied products for testing.

Appendix

Photos from selected treatments

Raw data for Fusarium basal rot score

	Treatment												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	In-furrow treatment							HWT			Controls		
Bulb no.	AHDB9816	AHDB9717	AHDB9725	AHDB9719	AHDB9741	AHDB9726	AHDB9718	AHDB9719 0.4 L/ha	AHDB9719 0.8 L/ha	AHDB9719 1.2 L/ha	Untreated in- furrow	Untreated HWT	Untreated non inoc
1	0	7	0	7	10	6	1	7	0	1	0	9	0
2	0	7	10	7	0	0	1	6	0	0	1	9	1
3	1	10	0	0	0	6	0	2	0	0	9	2	0
4	0	6	0	1	0	0	1	7	9	1	0	0	0
5	7	7	6	0	0	0	0	3	4	0	9	1	0
6	8	1	10	0	0	0	0	0	6	0	9	10	0
7	0	0	8	0	0	0	0	0	0	6	10	10	1
8	10	1	8	6	5	7	2	0	1	0	1	0	0
9	10	7	0	6	0	0	0	0	0	0	1	2	6
10	7	0	0	0	0	0	0	7	1	1	1	9	0
11	5	7	1	0	0	0	0	1	3	1	0	9	0
12	0	1	8	9	0	6	8	7	0	0	0	9	1
13	7	3	9	0	6	2	0	8	9	0	0	2	0
14	0	7	6	0	0	0	8	3	0	0	0	0	0
15	0	0	0	0	0	7	0	2	0	0	9	1	2
16	0	0	0	0	0	0	1	0	5	0	0	10	0
17	0	0	6	0	2	4	0	0	0	6	9	0	0
18	8	0	0	1	0	9	0	1	7	1	1	7	0
19	2	0	0	0	7	9	0	0	0	0	6	0	0
20	0	5	0	0	1	0	0	7	0	0	0	0	0
21	0	9	1	0	8	0	0	0	0	0	7	10	0
22	6	6	6	9	0	0	4	0	0	1	0	0	1
23	0	0	0	6	0	8	0	0	0	0	10	0	0
24	10	0	0	0	0	8	0	0	7	7	9	7	0
25	0	1	0	0	3	0	0	0	0	1	0	0	0
26	0	0	0	0	8	0	0	0	0	8	10	10	0
27	0	0	0	0	1	0	6	0	0	0	1	10	1
28	0	9	0	0	0	7	0	2	0	8	0	10	0
29	4	0	1	0	7	7	7	0	0	0	3	1	0
30	0	0	10	0	3	0	1	0	0	0	1	2	0
31	7	1	0	0	0	6	10	1	8	0	0	9	0
32	7	6	0	0	7	1	0	4	1	0	6	9	1
33	10	6	5	0	9	9	9	0	1	1	0	10	0
34	0	0	2	0	1	1	0	3	9	0	6	8	0
35	0	3	2	0	2	0	6	0	0	1	3	7	0
36	0	7	6	2	0	6	9	0	1	1	5	6	0
37	7	0	1	0	0	8	0	0	0	1	0	0	0
38	6	0	8	0	0	0	6	0	0	0	0	0	1
39	0	1	1	7	0	0	6	9	0	0	0	6	0
40	0	1	0	9	0	1	9	6	0	1	0	7	0