SCEPTREPLUS

Final Trial Report

Trial code:	SP: 44
Title:	Control of Ornamental rust (in Heuchera)
Crop	Group; Ornamentals - Heuchera
Target	Rust (*Puccinia heucherae*)
Lead researcher:	Guy Johnson
Organisation:	RSK ADAS Ltd.
Period:	1st July 2019 – 31st January
Report date:	31st January 2021
Report authorised by:	Angela Huckle
Report author:	Guy Johnson Dave Kaye
ORETO Number: (certificate should be attached)	ORETO 409

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

29/01/2020
Date


Authors signature

Trial Summary

Introduction

Rusts are specialised fungal pathogens which affect the aerial components of plants. Over 150 genera of rust have been described infecting thousands of plant species, including ornamental types. Heuchera rust is caused by *Puccinia heucherae* with disease severity dependent on the general susceptibility of individual varieties and the environmental conditions under which these plants are grown.

P. heucherae has two known reproductive forms, small white basidiospores (infective spores) which give rise to larger orange-brown teliospores (sexual resting spores). Targeting treatments to prevent the formation of the asexual basidiospores will directly impact teliospore production, preventing, or limiting further cycles of infection. The monocyclic nature of *P. heucherae*, including the absence of a uredospore stage, means disease control can be straight forward once the initial infection is controlled. However, Heuchera sales are dependent on aesthetics and the presence of even a low level of rust can render plants unmarketable. As such, poorly managed outbreaks can have profound economic consequences to businesses.

UK growers are largely reliant on fungicides to treat rust. With the ongoing loss of many azole group fungicides, it is becoming increasingly difficult to develop effective spray programs that can meet fungicide resistance guidelines. In addition, there are currently no bio-protectants approved for control of rust diseases. The aim of this work was to screen new fungicides and bio-protectants for disease control efficacy and phytotoxicity in Heuchera to provide new management options for rust diseases in ornamental crops.

Methods

A crop protection product efficacy trial was established on the 28th March 2020 on the hard standing at ADAS Boxworth and included the commercial Heuchera variety: Key Lime Pie, a variety known to be susceptible to *P. heucherae*. The trial consisted of a four block, randomised design, with four replicate plants per treatment.

The heuchera plants selected for this work had a history of rust infection to maximise the likelihood of rust infection developing during the trial. The foliage of these plants was allowed to die back completely at the end of 2019 and all remaining infected decaying leaf tissue, or plant debris was removed. In 2020, this material was combined and reintroduced evenly around newly emerging plant growth, which was free of rust infection. In addition, heuchera plants of a different variety displaying moderate to severe rust symptoms were placed as spreader plants on the 24th April around the trial area, close to the trial plants, to promote spread of spores via water splash from rain/overhead irrigation.

Ten treatments (Table 1), including an untreated water control and the commercial standard programme of Amistar (azoxystrobin) and Plover (difenoconazole), were applied at four application timings (A-D) using an Oxford precision sprayer. Application A was applied as soon as rust symptoms were first observed on the 30th April 2020, with application B made after rust had further developed on the 15th May. Applications C and D were made on the 29th May and the 12th June. Plants were assessed for rust incidence and severity with an initial assessment carried out at the start of the trial when spreader plants were added, followed by further assessments before each application and two weeks following the final treatment.

Table 1. Fungicide treatment details.

Treatment number	Treatment: product name or AHDB code	Rate of active substance (ml or g a.s./ha)	Rate of product (l or kg/ha)	Application code
1	Untreated	N/A	N/A	N/A
2	Amistar	175	0.7 litres/ha	A,C
2	Plover	62.5	0.25 kg/ha	B,D
3	AHDB9851	757.5	0.15 kg/ha	A-D
4	AHDB9911	150	0.75 Litres/ha	A-D
5	AHDB9872	112.5	0.225 Litres/ha	A-D
6	AHDB9853	75	0.75 Litres/ha	A-D
7	AHDB9862	N/A	1.5 kg/ha	A-D
8	AHDB9967	35.37	0.6% Litres	A-D
9	AHDB9852	640	3.2 Litres/ha	A-D
10	AHDB9843	380	1 Litres/ha	A-D

At each assessment date, plots were assessed for rust incidence and severity as below:

- Disease incidence was scored as the percentage of (whole) plants displaying rust symptoms.
- Disease severity was scored from 0 to 3 for each plant.
    - 0 = No symptoms.
    - 1 = First visible symptoms (less than pustules on leaves).
    - 2 = 6+ pustules up to 49% pustule coverage.
    - 3 = Severe infection, 50%+ pustule coverage.
- Crop safety was recorded at each assessment on a scale of 0 to 10 with 0 = complete plant death (100% crop damage) to 10 = no damage (0% crop damage).

Results

Despite the use of infected material and spreader plants, the overall incidence and severity of rust was low in the trial.

Efficacy

Rust incidence: The incidence of rust was significantly higher ($p<0.05$) in the untreated plots compared with treated plots at the preliminary assessment (30th April), before the first treatment application (Table 2). As a consequence of this, a covariate was used in the statistical analysis to compensate. Three products with preventative action, AHDB9911, AHDB9872 and AHDB9853 were included in this work, but were applied after symptoms were first observed, which may have impacted their efficacy.

At the second assessment (14th May), plots treated with AHDB9967 and AHDB9843 showed a significant ($p<0.05$) increase in incidence of *P. heucherae* compared with the untreated control, while other treatments showed with no significant reductions in incidence at this time. The apparent decrease in disease incidence recorded between the first and second assessments was as a consequence of the emergence of new foliage free of rust symptoms and old leaves senescing and dying off.

Rust incidence had increased by the third assessment (28th May, following applications A and B) where all treatments apart from AHDB9843 and AHDB9967 significantly reduced ($p<0.05$) incidence of *P. heucherae* compared with the untreated control. As with assessment 2, AHDB9967 significantly increased disease incidence at this and the fourth assessment date (11th June). No product resulted in significant reductions in *P. heucherae* at the final two assessments.

Table 2. Effect of crop protection products on mean rust incidence for each of five assessment dates.

	Date				
Treatment	**30-April**	**14-May***	**28-May**	**11-Jun**	**25-Jun**
Untreated	*3.50*	1.32	12.85	2.35	4.15
Standard programme	*1.75*	3.33	1.90	0.10	0.10
AHDB9851	*0.95*	2.55	4.30	0.50	0.50
AHDB9911	*1.60*	3.89	6.75	0.10	0.15
AHDB9872	*0.55*	3.67	0.65	2.00	1.15
AHDB9853	*1.95*	0.20	0.15	0.15	0.00
AHDB9862	*1.95*	0.60	0.65	0.00	0.00
AHDB9967	*1.40*	8.12	23.90	6.25	2.10
AHDB9852	*0.30*	3.17	4.65	0.95	2.15
AHDB9843	*0.55*	5.72	9.80	6.25	3.80
P value	<0.001	<0.001	<0.001	0.002	0.384
d.f.	27	26	27	27	27
s.e.d.	0.589	1.616	2.734	1.458	2.111
l.s.d.	1.208	3.322	5.610	2.992	4.332
	Not significantly different from untreated control (p>0.05)				
	Significantly lower than untreated control (p<0.05)				
	Significantly greater than untreated control (p<0.05)				

*Data for 14th May uses covariate.

Rust severity: There was a significant increase in Heuchera rust severity compared to the untreated control observed for AHDB9872 and AHDB9852 at the first assessment (30th April), before any treatments were applied and this was factored into future statistical analyses using a covariate. Throughout the trial period only two products, AHDB9853 and AHDB9862 resulted in significant reductions ($p<0.05$) in rust severity compared with the untreated control. AHDB9853 significantly reduced rust symptom severity from 0.60% in the untreated to 0.05% at assessment 3 (28th May, following applications A and B) while AHDB9862 reduced rust severity from 0.30% in the untreated to 0.00% at assessment 4 (11th June, following applications A-C).

Despite statistically significant differences between treatments and the untreated control, disease severity was very low, with no plants moderately to heavily symptomatic of rust infection. Therefore, any differences between the treatment effects and the untreated control are marginal and conclusions based on this data alone must be reviewed critically; however, several of these products have been tested in other SCEPTREplus projects e.g. plum rust, and these results confirm the effects seen in these other trials.

Table 3. Effect of crop protection products on mean rust severity (%) for each of five assessment dates.

	Mean Rust Severity (all leaves)				
Date	**30-April**	**14-May***	**28-May**	**11-Jun**	**25-Jun**
Treatment					
Untreated	*0.45*	0.50	0.60	0.30	0.20
Standard programme	*0.30*	0.70	0.25	0.05	0.05
AHDB9851	*0.25*	0.35	0.35	0.15	0.10
AHDB9911	*0.35*	0.50	0.30	0.05	0.10
AHDB9872	*0.10*	0.40	0.65	0.20	0.10
AHDB9853	*0.30*	0.15	0.05	0.10	0.00

AHDB9862	*0.45*	0.25	0.25	0.00	0.00
AHDB9967	*0.40*	0.70	0.60	0.55	0.30
AHDB9852	*0.15*	0.35	0.40	0.30	0.25
AHDB9843	*0.20*	0.55	0.65	0.35	0.25
P value	0.019	0.078	0.005	0.04	0.30
d.f.	27	27	27	27	27
s.e.d.	0.103	0.180	0.192	0.127	0.136
l.s.d.	0.211	0.369	0.393	0.260	0.279
	Not significantly different from untreated control (p>0.05)				
	Significantly different from untreated control (p<0.05)				

Phytotoxicity

No phytotoxic symptoms developed following the application of any test treatments at any assessment date. All products can be considered crop safe at the rates tested.

Conclusions

- Heuchera rust incidence and severity levels remained low for the duration of the trial and significant differences must be reviewed with caution.
- Both AHDB9853 and AHDB9862 significantly reduced rust incidence and severity compared with the untreated control.
- AHDB9852, a bio-protectant, significantly reduced rust incidence compared with the untreated control at the third assessment, demonstrating a potential place of bio-protectants in treating rust. AHDB9852 has also demonstrated efficacy against rust (*Tranzschelia discolor*) in the AHDB SCEPTREplus plum rust trial.
- AHDB9967 and AHDB9843 increased the incidence of rust during at least one assessment.
- No phytotoxic symptoms developed in any plants following treatment.
- Greater confidence can be given to treatments that reduced both disease severity and disease incidence.
- Additional testing under a greater disease pressure is required to increase the confidence of these results.
- Further work is required to develop the best combination of treatments for an IPM programme.

Take home message:

All products apart from AHDB9967 appeared to reduce the incidence of rust in heuchera at one assessment, whilst AHDB9853 and AHDB9862 reduced disease severity. Overall disease levels were low, and this work should be completed under greater disease pressure to confirm these results.

Full Report

Objectives

Provide new management options for rust diseases in ornamental crops, and to screen new fungicides and bio-protectants for disease control efficacy and phytotoxicity in Heuchera.

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**
EPPO PP1/135(4)	Phytotoxicity assessment	None
EPPO PP1/152(4)	Guideline on design and analysis of efficacy evaluation trials	None
EPPO PP1/225 (2)	Minimum effective dose	None
EPPO PP1/181 (4)	Conduct and reporting of efficacy evaluation trials including good experimental practice	None
EPPO PP 1/214(3)	Principles of acceptable efficacy	None
EPPO PP 1/224(2)	Principles of efficacy evaluation for minor uses	None

There were no deviations from EPPO guidance.

Test site

Item	**Details**
Location address	ADAS, Boxworth, CB23 4NN: Hard standing (outdoors)
Crop	Heuchera
Cultivar	Key Lime Pie (rust susceptible variety)
Soil or substrate type	Potting compost John Innes No. 3
Agronomic practice	Preventative vine weevil drench on the 6th May 2020 at a rate of 4 l/m^2. Overhead watering by hand or automated irrigation system during hot spells additional watering to increase disease pressure.
Prior history of site	2019 various potted plants for trials including heuchera

Trial design

Item	**Details**
Trial design:	Randomised Block
Number of replicates:	5
Row spacing:	5 cm
Plot size: (w x l)	0.5 m X 0.5 m
Plot size: (m^2)	0.25
Number of plants per plot:	5
Leaf Wall Area calculations	N/A

Treatment details

AHDB Code	**Active substance**	**Product name/ manufacturers code**	**Formulation batch number**	**Content of active substance in product**	**Formulation type**
N/A	N/A	Untreated	N/A	N/A	N/A
N/A	azoxystrobin	Amistar	GR9E00038	250 g/L	Suspension concentrate
N/A	difenoconazole	Plover	Not Known	250 g/L	Emulsifiable concentrate
AHDB9851	Confidential				
AHDB9911	Confidential				

AHDB Code	Active substance	Product name/ manufacturers code	Formulation batch number	Content of active substance in product	Formulation type
AHDB9872	Confidential				
AHDB9853	Confidential				
AHDB9862	Confidential				
AHDB9967	Confidential				
AHDB9852	Confidential				
AHDB9843	Confidential				

Methods, assessments and records

Fungicides were applied following standard programme timings, with the application of the first treatments (A) when symptoms were first observed (April 30th, BBCH 51). Application B was applied after rust symptoms had developed further (May 15th, 14 days after application A). Applications C and D were applied 14 days after each previous application on May 29th and June 12th respectively.

Five disease assessments were carried out, the first four timed to coincide with treatment applications. The first disease assessment was carried out at application A, with subsequent assessments carried out 24 hours before applications B, C and D. A final assessment was completed two weeks after the final treatment application.

Application schedule

Treatment number	Treatment: product name or AHDB code	Rate of active substance (ml or g a.s./ha)	Rate of product (l or kg/ha)	Application code
1	Untreated	N/A	N/A	N/A
2	Amistar	175	0.7 L / ha	A,C
2	Plover	62.5	0.25 Kg / ha	B,D
3	AHDB9851			A-D
4	AHDB9911			A-D
5	AHDB9872			A-D
6	AHDB9853			A-D
7	AHDB9862			A-D
8	AHDB9967			A-D
9	AHDB9852			A-D
10	AHDB9843			A-D

Application details

	Application A	Application B	Application C	Application D
Application date	30/04/2020	15/05/2020	29/05/2020	12/06/2020
Time of day	09:00	09:30	10:45	11:00
Crop growth stage (Max, min average BBCH)	51	55	59	67
Crop height (cm)	13	15	16	18
Crop coverage (%)	50	55	60	65
Application Method	Spray	Spray	Spray	Spray
Application Placement	Foliage	Foliage	Foliage	Foliage
Application equipment	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer
Nozzle pressure	2.0	2.0	2.0	2.0
Nozzle type	F04/110	F04/110	F04/110	F04/110
Nozzle size	Flat fan	Flat fan	Flat fan	Flat fan
Application water volume/ha	400.00	400.00	400.00	400.00
Temperature of air - shade (°C)	N/A	N/A	N/A	N/A
Relative humidity (%)	N/A	N/A	N/A	N/A
Wind speed range (m/s)	0	0	0	0
Dew presence (Y/N)	N	N	N	N
Temperature of soil - 2-5 cm (°C)	N/A	N/A	N/A	N/A
Wetness of soil - 2-5 cm	N/A	N/A	N/A	N/A
Cloud cover (%)	N/A	N/A	N/A	N/A

*Climate data was not collected as the plants were treated into a polytunnel to prevent drift to be sprayed and then immediately moved back to the hard standing.

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
Rust	*Puccinia heucherae*	PUCCHC	3.50% incidence 0.45% severity	3.50% incidence 0.45% severity	4.15% incidence 0.20% severity

Disease assessment details

A preliminary disease and vigour assessment was performed at the start of the trial, followed by the first treatment application. All assessments were completed at 14-day intervals.

At each date plots were assessed for rust incidence and severity.

- Disease incidence was scored as percentage of whole plant displaying rust symptoms.
- Disease severity was scored from 0 to 3 for the average of the whole plant.
    - 0 = No symptoms.
    - 1 = First visible symptoms (less than pustules on leaves).
    - 2 = 6+ pustules up to 49% pustule coverage.
    - 3 = Severe infection, 50%+ pustule coverage.
- Crop safety was recorded at each assessment on a scale of 0 to 10 with 0 = complete plant death (100% crop damage) to 10 = no damage (0% crop damage).

Phytotoxicity was recorded using the following scale:

Table 4. Scale used for the assessment of the extent of phytotoxic damage in treated plots.

Crop tolerance score	Equivalent to crop damage (% phytotoxicity)
0	complete crop kill 100%
1	80-95% damage
2	70-80%
3	60-70%
4	50-60%
5	40-50%
6	25-40%
7	15-25%
8	10-15%
9	5-10%
10	no damage

Assessment schedule

Evaluation date	Evaluation Timing (DA)*	Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotoxicity)	Assessment
30/04/2020	0	51	Preliminary	Rust incidence and severity
14/05/2020	13	55	Efficacy Phytotoxicity	Rust incidence and severity Crop safety
28/05/2020	27	59	Efficacy Phytotoxicity	Rust incidence and severity Crop safety
11/06/2020	41	67	Efficacy Phytotoxicity	Rust incidence and severity Crop safety
25/06/2020	55	69	Efficacy Phytotoxicity	Rust incidence and severity Crop safety

* DA – days after application

Statistical analysis

The first assessment on the 30th April showed significant differences in rust levels between some treatments before any applications were made; a covariate analysis was therefore completed on all subsequent dates using data from the first assessment as a covariate to compensate for variability. Statistical differences between treatments and the control, as a result of the covariate, were found at incidence assessment 2 (14th May).

Results

Phytotoxicity

No phytotoxic symptoms developed following the application of any test treatments at any assessment date. All products can be considered crop safe at the rates tested.

Efficacy

Incidence: The incidence of rust was significantly higher ($p<0.05$) in the untreated plots compared with treated plots at the preliminary assessment (30th April), before the first treatment application (Table 2). As a consequence of this, a covariate was therefore implemented for analysis of rust incidence and severity to account for this. This showed that there were significant reductions in rust at the second assessment of incidence only (May 14th). No significant effects were found by using the covariate analysis with ANOVA for rust severity at any other assessment date and hence the original data is presented.

Three products with preventative action, AHDB9911, AHDB9872 and AHDB9853 were included in this work. As all products were applied after symptoms were first observed, this may have impacted their efficacy.

At the second assessment (14th May), plots treated with AHDB9967 and AHDB9843 showed a significant ($p<0.05$) increase in incidence of *P. heucherae* compared with the untreated control, with no significant reductions in incidence recorded in other treatments at this time. The decrease in disease incidence recorded between the first and second assessments was a consequence of the emergence of new foliage free of rust symptoms.

Rust incidence increased by the third assessment (28th May, following applications A and B). All treatments apart from AHDB9843 and AHDB9967 significantly reduced ($p<0.05$) incidence of *P. heucherae* compared with the untreated control. As with assessment 2, AHDB9967 significantly increased disease incidence at this and the fourth assessment date (11th June). No product gave significant reductions in *P. heucherae* at the final two assessments

Table 5. Effect of fungicides on mean rust incidence (scored as a percentage of whole plant displaying rust symptoms) for each of five assessment dates.

	Date				
Treatment	**30-April**	**14-May***	**28-May**	**11-Jun**	**25-Jun**
Untreated	*3.50*	1.32	12.85	2.35	4.15
Standard programme	*1.75*	3.33	1.90	0.10	0.10
AHDB9851	*0.95*	2.55	4.30	0.50	0.50
AHDB9911	*1.60*	3.89	6.75	0.10	0.15
AHDB9872	*0.55*	3.67	0.65	2.00	1.15
AHDB9853	*1.95*	0.20	0.15	0.15	0.00
AHDB9862	*1.95*	0.60	0.65	0.00	0.00
AHDB9967	*1.40*	8.12	23.90	6.25	2.10
AHDB9852	*0.30*	3.17	4.65	0.95	2.15
AHDB9843	*0.55*	5.72	9.80	6.25	3.80
P value	<0.001	<0.001	<0.001	0.002	0.384
d.f.	27	26	27	27	27
s.e.d.	0.589	1.616	2.734	1.458	2.111
l.s.d.	1.208	3.322	5.610	2.992	4.332
	Not significantly different from untreated control ($p>0.05$)				
	Significantly lower than untreated control ($p<0.05$)				
	Significantly greater than untreated control ($p<0.05$)				

Severity: Significant differences for AHDB9872 and AHDB9852 were present at the first assessment (30th April) before any treatments were applied and this was factored into future statistical analyses using a covariate. Throughout the trial period only two products gave significant reductions ($p<0.05$) in rust severity compared with the untreated control. AHDB9853 significantly reduced rust symptom severity from 0.60% in the untreated to 0.05% at assessment 3 (28th May, following applications A and B). AHDB9862 reduced rust severity from 0.30% in the untreated to 0.00% at assessment 4 (11th June, following applications A-C).

Despite statistically significant differences between treatments and the untreated control, disease severity was very low, with no plants heavily symptomatic of rust infection. Any differences between the recorded treatment effects and the untreated control are marginal and conclusions based on this data alone must be reviewed critically; however, several of these products have been tested in other SCEPTREplus and these results complement efficacy seen in these trials.

Table 6. Mean rust severity (%) at each assessment date, based on the 0-3 scoring criteria (0: no symptoms, 1: up to 5 pustules per leaf, 2: 6+ pustules up to 49% pustule coverage, 3: 50%+ pustule coverage).

	Mean Rust Severity (all leaves)				
Date	**30-April**	**14-May***	**28-May**	**11-Jun**	**25-Jun**
Treatment					
Untreated	*0.45*	0.50	0.60	0.30	0.20
Standard programme	*0.30*	0.70	0.25	0.05	0.05
AHDB9851	*0.25*	0.35	0.35	0.15	0.10

AHDB9911	*0.35*	0.50	0.30	0.05	0.10
AHDB9872	*0.10*	0.40	0.65	0.20	0.10
AHDB9853	*0.30*	0.15	0.05	0.10	0.00
AHDB9862	*0.45*	0.25	0.25	0.00	0.00
AHDB9967	*0.40*	0.70	0.60	0.55	0.30
AHDB9852	*0.15*	0.35	0.40	0.30	0.25
AHDB9843	*0.20*	0.55	0.65	0.35	0.25
P value	0.019	0.078	0.005	0.04	0.30
d.f.	27	27	27	27	27
s.e.d.	0.103	0.180	0.192	0.127	0.136
l.s.d.	0.211	0.369	0.393	0.260	0.279
	Not significantly different from untreated control (p>0.05)				
	Significantly different from untreated control (p<0.05)				

Discussion

Rust typically infects heuchera twice per year, during the spring and autumn. This trial was originally set up during the autumn of 2019, but as a consequence of low levels of disease development, the trial was established again in spring 2020. The trial plants from 2019 were reused and old inoculum, collected from the previous season was reintroduced as tissue debris to increase the likelihood of a greater degree of infection developing during 2020.

Rust symptoms were first observed on plants on April 30th 2020, one day prior to application A. As a consequence of the early development of symptoms, no products had been applied preventatively. At this time, significant differences ($p<0.05$) were found between the plots which were allocated for treatments compared with those which would remain untreated. The potential confounding influence of variable rust levels at the start of the trial alongside the low rust incidence and severity levels means that interpretation and confidence in these results is problematic. While there were significant differences between treatments, these were small and caution must be taken in their interpretation.

In this trial, the rust disease level in the untreated plants reached a maximum on May 28th, before subsequently declining. This was as a consequence of a new flush of plant foliage growth due to improved growing conditions. This new growth remained uninfected as the spring cycle of rust infection had apparently ended.

At assessment 3, a significant reduction in rust incidence ($p<0.05$) was recorded for plants treated with the standard programme (Amistar and Plover), AHDB9851, AHDB9911, AHDB9872, AHDB9853, AHDB9862, and AHDB9852 compared with the untreated control. No other significant reductions in rust incidence were seen at subsequent assessments. AHDB9967 and AHDB9843 did not result in a reduction in rust incidence compared with the untreated at any assessment date.

Significant differences in severity were present at the first assessment before any treatments were applied for AHDB9872 and AHDB9852. Two products gave significant reductions in severity, AHDB9853 reduced rust severity at assessment 3 and AHDB9862 reduced rust severity at assessment 4. Despite the statistically significant differences between treatments, they are marginal and should be reviewed critically. Greater confidence should be given to products that reduced both disease incidence and severity.

Several succinate dehydrogenase inhibitor (SDHI) fungicides were tested in this work including AHDB9911, AHDB9853 and AHDB9872. Like most SDHIs, AHDB9911 and AHDB9853 have broad-spectrum activity which inhibits spore germination, germ tube development, and mycelial growth. Past research has found that both these products have limited curative effects and therefore should be used preventatively. In this work, both AHDB9911 and AHDB9853 reduced rust incidence, despite being applied curatively, and preventative application may have

enhanced their control. AHDB9911 was also effective at reducing plum rust (*Tranzschelia discolor*) in recent SCEPTREplus trial work (SP41). However, it should be noted that *T. discolor* differs from *P. heucherae* as the primary infective propagules are uredospores rather than basidiospores.

AHDB9853 reduced the incidence and severity of heuchera rust at the third assessment date, following two treatments applications. This treatment is designed to act preventatively, binding to the cuticle of the leaf, preventing infection. It can further reduce sporulation by reducing spore germination, preventing the penetration of the cells, and suppressing mycelial growth. AHDB9872 also significantly reduced rust incidence at the third assessment.

SDHI fungicides belong to FRAC group 7 and perform best when applied early on in fungicide programmes. The SDHIs tested in this work could potentially be incorporated into a resistance management programme, alongside the industry standard programme of Amistar (azoxystrobin, FRAC group 11) and Plover (difenoconazole, FRAC group 3).

The new generation azole AHDB9862 was the only other product in this trial to reduce the incidence and severity of rust symptoms and is a potentially useful product for disease management. However, as it belongs to the same FRAC group as Plover (FRAC group 3), its use in a fungicide management programme would need to be carefully considered.

AHDB9851, a strobilurin fungicide, claims on-label protectant activity, however it gave significant control of rust incidence compared with the untreated control when applied after the appearance of rust symptoms. Past work on plum rust found that AHDB9851 was an excellent control option, preventing rust development when applied protectively, outperforming the industry standard used in that work. AHDB9851 belongs to FRAC group 11, the same FRAC group as azoxystrobin with a good degree of rust control anticipated as a consequence. Guidance states that strobilurin fungicides should be alternated with actives from other FRAC groups as part of a resistance management programme and careful consideration is therefore needed before integrating this into a rust fungicide programme.

AHDB9852 reduced rust disease incidence at assessment 3 but had no effect on rust severity. This bio-protectant gave good control against plum rust where it reduced spore production, spore germination, and inhibited the formation of telia. Reducing the number of teliospores during the season is a powerful management tool, as fewer resting spores overwintering will result in a lower level of infection the following season. As a consequence of this, AHDB9852 could become a valuable bio-protectant to use within resistance management programmes.

In this work AHDB9967 significantly increased the incidence of heuchera rust at three assessments. This product has previously been shown to desiccate superficial fungal mycelia, sporangia, and spores, exposing the contents of the cells to the atmosphere, as well as killing infected plant cells, cutting off the supply of nutrients to the hyphae.

Overall, due to low levels of rust development, it may be necessary to repeat this work under greater disease pressure or use a different susceptible ornamental species to confirm the results presented here.

Conclusions

- Rust incidence and severity levels remained low for the duration of the trial and significant differences must be reviewed with caution.
- Both AHDB9853 and AHDB9862 significantly reduced rust incidence and severity compared with the untreated control.
- AHDB9852, a bio-protectant, significantly reduced rust incidence compared with the untreated control at the third assessment, demonstrating the place of bio-protectants in treating rust.
- AHDB9967 and AHDB9843 increased the incidence of rust during at least one assessment.
- AHDB9851, AHDB9911, and AHDB9852 have demonstrated efficacy against rust (*Tranzschelia discolor*) in the AHDB SCEPTREplus plum rust trial.

- No phytotoxic symptoms developed any plants following treatment.
- Greater confidence can be given to treatments that reduced both disease severity and disease incidence.
- Additional testing under a greater disease pressure is required to increase the confidence of these results.
- Further work is required to develop the best IPM programmes incorporating the most effective products identified in this work.

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Appendix

a. Crop diary – events related to growing crop

Crop	Cultivar	Planting date	Bed width (containerised crop)
Heuchera	Key lime	25/03/2020	0.5 m x 0.5 m

Previous cropping

Year	Crop
2018/19	Heuchera
2017	Mixed species
2016	Mixed species

Cultivations

Date	Description
	None as the crop is containerized.

Active ingredients(s)/fertiliser(s) applied to trial area

Date	Product	Rate (kg/ha)
	N/A	

Pesticides applied to trial area

Date	Product	Rate (L/ha)
06/05/2020	Nemasys L	4 L / m^2

b. Trial diary

Date	Event
30/04/2020	Timing A treatment application.
15/05/2020	Timing B treatment application. Trial assessment; crop phyto, Disease incidence, disease severity.
29/05/2020	Timing C treatment application. Trial assessment; crop phyto, Disease incidence, disease severity.
12/06/2020	Timing D treatment application. Trial assessment; crop phyto, Disease incidence, disease severity.
25/07/2020	Trial assessment; crop phyto, weed cover.

c. Photographs.

Figure 1. Heuchera leaf with rust pustules (*top left*). Trial layout on the hard standing at Boxworth (*bottom left*). Healthy plant displaying little to no rust (*right*).

d. Climatological data during study period

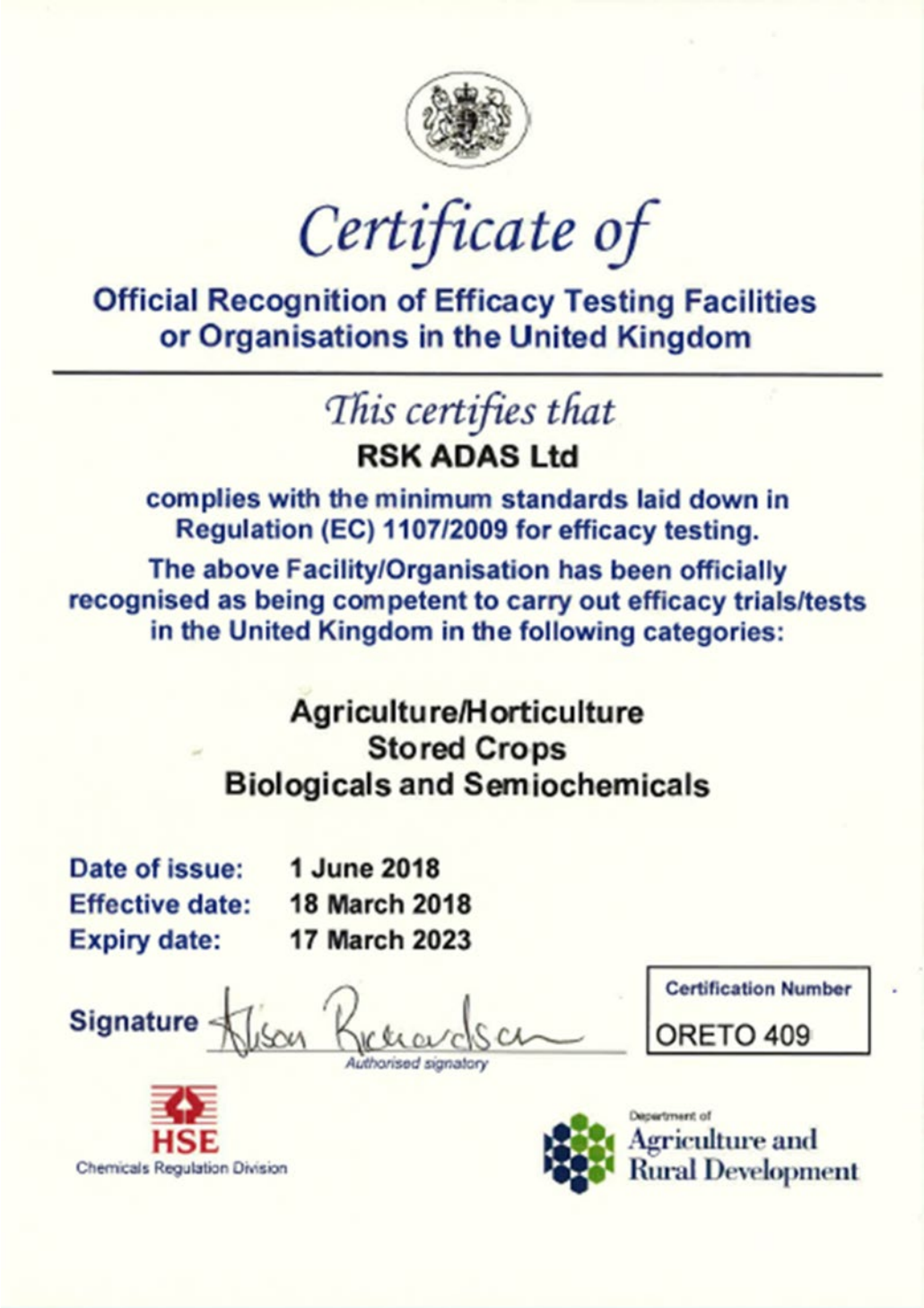
Date	Min Temp (°C)	Max Temp(°C)	Average Temp(°C)	Average Humidity(%rh)
28-04-20	6.40	10.10	7.68	88.26
29-04-20	5.70	12.10	8.84	87.27
30-04-20	5.80	11.70	8.60	86.14
1-05-20	6.50	13.70	9.82	79.24
2-05-20	6.20	15.60	10.88	71.74
3-05-20	7.60	14.00	10.99	77.41
4-05-20	6.80	15.10	10.68	80.51
5-05-20	3.80	13.80	8.76	72.80
6-05-20	1.70	16.90	9.72	70.56
7-05-20	5.10	21.10	13.44	71.26
8-05-20	12.30	22.80	17.62	67.10
9-05-20	10.60	23.20	17.60	57.83
10-05-20	5.00	14.40	9.54	79.88
11-05-20	3.20	10.50	6.92	66.82
12-05-20	0.40	12.80	7.66	67.88
13-05-20	4.10	10.80	7.39	66.69
14-05-20	1.10	12.00	7.38	64.32
15-05-20	4.10	16.40	10.40	64.16
16-05-20	4.80	15.60	10.81	67.72
17-05-20	8.40	18.80	13.84	62.47
18-05-20	9.70	21.70	15.60	66.46
19-05-20	12.10	23.80	17.60	69.97
20-05-20	12.10	26.60	19.80	68.48

21-05-20	12.10	24.60	19.22	60.92
22-05-20	12.60	20.20	17.40	56.25
23-05-20	9.90	17.40	13.35	67.64
24-05-20	10.90	19.60	15.17	71.20
25-05-20	10.20	23.30	17.30	61.67
26-05-20	10.40	23.00	17.63	60.05
27-05-20	12.50	22.50	17.43	65.99
28-05-20	8.80	20.70	14.81	66.06
29-05-20	6.90	21.60	14.95	55.85
30-05-20	6.80	23.10	15.33	64.01
31-05-20	7.80	22.90	15.96	62.23
1-06-20	8.50	24.10	16.54	66.81
2-06-20	8.70	22.40	15.98	69.64
3-06-20	10.10	16.60	13.73	78.69
4-06-20	9.20	13.30	10.85	80.96
5-06-20	8.00	14.30	10.53	76.34
6-06-20	6.00	14.40	9.29	80.99
7-06-20	7.20	12.90	10.46	88.42
8-06-20	7.70	13.30	10.76	80.08
9-06-20	5.60	17.60	12.02	72.65
10-06-20	10.80	13.80	11.84	90.98
11-06-20	9.60	18.20	12.77	92.15
12-06-20	12.70	19.60	15.58	91.36
13-06-20	11.80	23.30	18.19	71.47
14-06-20	11.50	23.40	18.20	73.35
15-06-20	11.80	23.00	17.68	77.47
16-06-20	12.20	22.90	17.58	79.72
17-06-20	11.80	22.70	16.25	87.19
18-06-20	12.50	18.80	14.88	89.72
19-06-20	12.30	12.70	12.53	92.25

e. Trial design

AHDB9872	AHDB9851	AHDB9967	AHDB9862	AHDB9911	AHDB9853	AHDB9852	Untreated	AHDB9843	Standard
5	3	8	7	4	6	9	1	10	2
4	4	4	4	4	4	4	4	4	4
401	402	403	404	405	406	407	408	409	410
AHDB9872	AHDB9851	AHDB9862	Untreated	AHDB9911	AHDB9852	AHDB9967	Standard	AHDB9843	AHDB9853
5	3	7	1	4	9	8	2	10	6
3	3	3	3	3	3	3	3	3	3
301	302	303	304	305	306	307	308	309	310
AHDB9872	AHDB9967	AHDB9843	AHDB9911	AHDB9853	AHDB9851	Untreated	AHDB9862	Standard	AHDB9852
5	8	10	4	6	3	1	7	2	9
2	2	2	2	2	2	2	2	2	2
201	202	203	204	205	206	207	208	209	210
AHDB9872	AHDB9851	Standard	AHDB9862	AHDB9852	AHDB9843	AHDB9911	AHDB9967	AHDB9853	Untreated
5	3	2	7	9	10	4	8	6	1
1	1	1	1	1	1	1	1	1	1
101	102	103	104	105	106	107	108	109	110

f. ORETO certificate should be pasted in at end.



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Expiry date: 17 March 2023

Signature Alison Richardson
Authorised signatory

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