SCEPTREPLUS

# Final Trial Report

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|---|---|
| **Trial code:** | SP 41 |
| **Title:** | **Control of Rust in Plum** |
| **Crop** | Group; Top fruit - Plum |
| **Target** | Rust (*Tranzschelia discolor*) |
| **Lead researcher:** | Ruth D'urban-Jackson |
| **Organisation:** | RSK ADAS Ltd. |
| **Period:** | March 2019 – December 2019 |
| **Report date:** | 20 December 2019 |
| **Report author:** | Ruth D'urban-Jackson |
| **ORETO Number:** | 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.

**Date:** 20 December 2019 **Authors signature:**

# Trial Summary

## Introduction

There has been little planting of new plum orchards in the UK in the last 10-20 years in part due to the lack of profitability, which is largely influenced by losses to pest and diseases. The withdrawal of Systhane (myclobutanil) has left UK plum growers with a limited selection of fungicide actives, and none that target plum rust (*Tranzschelia discolor*). Whilst many diseases (*Botrytis*, *Colletotrichum* etc.) ruin the fruit, plum rust can cause severe and premature tree defoliation. The resulting reduction in photosynthesis during the growing season not only interferes with the current season's yield, but also that of the following year. In young trees that are still establishing, this can be particularly damaging. A field-based trial located in Cambridgeshire was set up to identify chemical and biological treatments to effectively manage this disease.

## Methods

Aldreth, Cambridgeshire, a region prone to high levels of plum rust was selected as the location for this work. A product efficacy trial consisting of a six block, randomised design was established on a newly planted plum orchard of the susceptible variety cv. Victoria on St Julian A rootstocks. The bare root maidens left cold storage and were immediately transported to the site in April 2019, where they were planted the same day. A one-time application of fertiliser was applied to the newly planted maidens, and drip-line irrigation was set up, to ensure plants received sufficient and regular water. The crop was treated according to commercial growing standards, except for the absence of grower fungicide inputs. The fruit was not harvested due to potential operator exposure risks associated with the products tested. A mature plum orchard nearby provided a natural source of airborne *T. discolor* inoculum to the trial area.

The first treatment application (30 July 2019) was applied preventatively, before any symptoms of plum rust. By 12 August, the first visual symptoms of *T. discolor* infection were observed, and the second treatment application was made. The third treatment application was then applied on 28 August, and the fourth on 12 September at a time when the plum rust was beginning to proliferate in the trial area. Product applications were made using a pressurized knapsack sprayer. Plants were assessed at each treatment date and 14 days following the final treatment application. At each assessment, rust disease incidence and severity, as well as crop safety were recorded. The late summer rains delayed disease progression, so although first symptoms were observed on 12 August, symptoms only started to increase noticeably by 12 September, so disease severity was only scored on the last three assessment dates, 12 September, 09 October and 31 October.

Each treatment plot within each of the six blocks contained two trees, both of which were assessed individually to give a total of 12 trees per treatment. Disease incidence was measured as the mean proportion of leaves with foliar rust symptoms, while severity was measured as the percentage of leaf surface area infected (average of all leaves on each tree) which was then given a score (0 = <1%, 1 = 1-10% of leaf surface covered, 2 = 11-40% leaf covered, and 3 = >40% leaf surface covered). At the final assessment, the percentage of defoliation was recorded, to establish where this was occurring prematurely.

## Results

Sufficient, and consistent levels of plum rust developed across the whole trial area, resulting in differences between treatments and the untreated plots. All plants in the untreated control plots developed symptoms, and many were completely defoliated by 31 October 2019 due to infection by *T. discolor* during the season.

<u>Incidence</u> – Rust disease developed rapidly in the trial from mid-September, where there was an increase in incidence in the untreated control plots from 5.8% on the 12 September to 94% by 31 October 2019 (Table 1). At this final assessment, there was a significant reduction in rust incidence for plots treated with AHDB 9851, AHDB 9911, and AHDB 9852, compared to the untreated controls. Of these, AHDB 9851 and AHDB 9852 treatments resulted in significantly lower rust incidence than the industry standard Amistar.

**Table 1.** Effect of treatments on mean plum rust incidence (% of whole canopy per plot affected) for each of six assessment dates.

| Date / Treatment | 12-Aug | 28-Aug | 12-Sept | 26-Sept | 09-Oct | 31-Oct |
|---|---|---|---|---|---|---|
| Untreated | 0.3 | 0.5 | 5.8 | 44.6 | 70.4 | 94.2 |
| Amistar | 0.5 | 1.0 | 2.5 | 10.3 | 22.9 | 23.8 |
| AHDB 9851 | 0.7 | 0.2 | 1.2 | 0.1 | 1.3 | 1.3 |
| AHDB 9911 | 0.8 | 0.5 | 3.0 | 19.2 | 38.7 | 39.1 |
| AHDB 9957 | 0.4 | 2.2 | 10.4 | 35.6 | 64.6 | 70.8 |
| AHDB 9872 | 0.8 | 4.3 | 8.1 | 69.2 | 93.3 | 98.3 |
| AHDB 9885 | 0.3 | 2.1 | 5.3 | 47.2 | 78.8 | 85.8 |
| AHDB 9852 | 0.6 | 3.3 | 8.2 | 6.6 | 14.3 | 15.4 |

| | |
|---|---|
| (blue) | Not significantly different from untreated control (p>0.05) |
| (orange) | Significantly less disease than untreated control (p<0.05) |
| (white) | Significantly more disease than untreated control (p<0.05) |

Severity – Disease severity scores highlighted treatments that slowed the progression of *T. discolor*, such as AHDB 9851 and AHDB 9852 and Amistar, compared with the untreated control plots (Table 2).

**Table 2**. Mean *T. discolor* - severity (score) per treatment for each of the six assessment dates.

| Date / Treatment | 12-Aug* | 28-Aug* | 12-Sept* | 26-Sept | 09-Oct | 31-Oct |
|---|---|---|---|---|---|---|
| Untreated | 0.0 | 0.0 | 0.0 | 1.6 | 1.8 | 2.0 |
| Amistar | 0.0 | 0.0 | 0.0 | 0.8 | 0.8 | 1.1 |
| AHDB 9851 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 |
| AHDB 9911 | 0.0 | 0.0 | 0.0 | 1.2 | 1.0 | 1.2 |
| AHDB 9957 | 0.0 | 0.0 | 0.0 | 1.7 | 1.7 | 2.2 |
| AHDB 9872 | 0.0 | 0.0 | 0.0 | 2.3 | 2.3 | 2.2 |
| AHDB 9885 | 0.0 | 0.0 | 0.0 | 1.8 | 1.8 | 2.2 |
| AHDB 9852 | 0.0 | 0.0 | 0.0 | 0.9 | 0.8 | 0.9 |

| | |
|---|---|
| (blue) | Not significantly different from untreated control (p>0.05) |
| (orange) | Significantly less than untreated control (p<0.05) |

* Disease levels not high enough to give accurate severity score at this date.

**Phytotoxicity**

No visible symptoms of phytotoxicity developed on any plants, after treatment, with any product, at any assessment date.

## Conclusions

- Four of the test products significantly reduced plum rust incidence and/or severity compared to the untreated controls at the final disease assessment date.
- Treatment AHDB 9851 resulted in a significantly lower disease incidence than the untreated control, on the final three disease assessments, and was significantly better than the industry standard on the final assessment date.
- Treatment AHDB 9852, a biological control agent, resulted in a significantly lower disease incidence than the untreated control, on the final three disease assessments.
- Treatment AHDB 9872 resulted in increased disease incidence at one assessment date and consistently had higher levels of rust compared with the untreated control, suggesting no efficacy towards *T. discolor*.
- No symptoms associated with phytotoxicity developed on any plants, at any date.
- Further work is required to establish the best integrated programmes incorporating the most effective products identified in this work.

## Take home message:

Treatments AHDB 9851, AHDB 9852 and AHDB 9911 reduced rust disease incidence, with AHDB 9851 providing better control than the industry standard Amistar at trial end.

## Objectives

To assess a range of fungicides for their safety and efficacy against plum rust (*Tranzschelia discolor*) in plum.

## 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 1/135(4) | Phytotoxicity assessment | None |
| PP 1/152(4) | Guideline on design and analysis of efficacy evaluation trials | None |
| PP 1/225(2) | Minimum effective dose | None |
| PP 1/181(4) | Conduct and reporting of efficacy evaluation trials including good experimental practice | None |
| PP 1/214(3) | Principles of acceptable efficacy | None |
| 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 | Millfield Orchard,<br>Haddenham,<br>Cambridgeshire,<br>CB6 3PW |
| Crop | Plum (first year maidens) |
| Cultivar | Victoria |
| Soil or substrate type | Soil |
| Agronomic practice | Modified commercial practice – no fungicide inputs by the host grower; crop remained unharvested (operator exposure risk). |
| Prior history of site | Small scale growing of ornamental crops. |

## Trial design

| Item | Details |
|---|---|
| Trial design: | Randomised block |
| Number of replicates: | 6 |
| Row spacing: | 1.5 m |
| Plot size: (w x l) | 1.0 m x 1.8 m |
| Plot size: ($m^2$) | 1.8 $m^2$ |
| Number of plants per plot: | 2 |
| *Leaf Wall Area calculations* | 1.5 m (width of trees) x 1.8 m (height) = 2.7 $m^2$ |

## Treatment details

| AHDB Code | Active substance | Product name/ manufacturer's code | Formulation batch number | Content of active substance in product | Formulation type |
|---|---|---|---|---|---|
| N/A | Water | Untreated | N/A | N/A | N/A |
| Standard | Azoxystrobin | Amistar | GRA8CC0203 | 20-25 % w/w | Suspension concentrate |
| AHDB 9851 | N/D | N/D | N/D | N/D | N/D |
| AHDB 9911 | N/D | N/D | N/D | N/D | N/D |
| AHDB 9957 | N/D | N/D | N/D | N/D | N/D |
| AHDB 9872 | N/D | N/D | N/D | N/D | N/D |
| AHDB 9885 | N/D | N/D | N/D | N/D | N/D |
| AHDB 9852 | N/D | N/D | N/D | N/D | N/D |

No adjuvants were included at any treatment application.
N/D* = content of active ingredient/s not disclosed by manufacturer

## 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 | N/A | - | - | A-D |
| 2 | Standard | 50-62.5 | 0.25 | A-D |
| 3 | AHDB 9851 | N/D | 0.15 | A-D |
| 4 | AHDB 9911 | N/D | 0.2 | A-D |
| 5 | AHDB 9957 | N/D | 1.0 | A-D |
| 6 | AHDB 9872 | N/D | 0.225 | A-D |
| 7 | AHDB 9885 | N/D | 4.0 | A-D |
| 8 | AHDB 9852 | N/D | 3.2 | A-D |

## Application details

| | Application A | Application B | Application C | Application D |
|---|---|---|---|---|
| **Application date** | 30/07/2019 | 12/08/19 | 28/08/19 | 12/09/19 |
| **Time of day** | 10:00 – 11:00 | 11:00 – 12:00 | 11:00 – 12:00 | 11:00 – 12:00 |
| **Crop growth stage (Max, min average BBCH)** | 72 | 79 | 87 | 91 |
| **Crop height (cm)** | 180 | 180 | 180 | 180 |
| **Crop coverage (%)** | 100 | 100 | 100 | 100 |
| **Application Method** | Spray | Spray | Spray | Spray |
| **Application Placement** | Foliar | Foliar | Foliar | Foliar |
| **Application equipment** | Oxford Precision Sprayer (Knapsack) | Oxford Precision Sprayer (Knapsack) | Oxford Precision Sprayer (Knapsack) | Oxford Precision Sprayer (Knapsack) |
| **Nozzle pressure** | 2 | 2 | 2 | 2 |
| **Nozzle type** | Flat Fan | Flat Fan | Flat Fan | Flat Fan |
| **Nozzle size** | 02F110 | 02F110 | 02F110 | 02F110 |
| **Application water volume L/ha** | 500 | 500 | 500 | 500 |
| **Temperature of air - shade (°C)** | 24.3 | 22.8 | 23.0 | 21.0 |
| **Relative humidity (%)** | 55.9 | 70.3 | 62.8 | 68.8 |
| **Wind speed range (m/s)** | 4.5 | 3.3 | 2.1 | 2.8 |
| **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 (%)** | 90 | 50 | 25 | 75 |

* Soil wetness and soil temperature do not impact the establishment and progression of plum rust so were not recorded.

To ensure treatment sprays did not hit surrounding plots, a plastic sheet (2 m x 3 m) was held up to encircle the 2 trees in the plot (Appendix C, image 2). The sheet was washed thoroughly with water between each different product application. Trees were pruned to remain at 1.8 m at all times throughout the trial, to be in line with the *leaf wall area* (see Trial design section).

**Untreated levels of 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 |
|---|---|---|---|---|---|
| Plum rust | *Tranzschelia discolor* | TRANDI | 0% | 5% | 100% |

No pests/pest damage were recorded on any plants at any assessment date.

The trial was located downwind from a nearby (300 m) mature plum orchard, where airborne inoculum of *T. discolor* would have been able to spread from naturally infected trees.

## Assessment details

One year old cv. Victoria maidens on St. Julien A rootstock were planted on 16 April 2019, and a drip irrigation system was set up (Appendix C, image 1). All trees had broken bud and leaves fully emerged by trial start (30 July 2019). A preliminary disease assessment was performed at the trial start, immediately followed by the first treatment application (pre-symptom). The second assessment was performed once first symptoms were observed (12 August 2019), which was followed by the second treatment application. The third and fourth assessments were subsequently completed at 14 day intervals (Table 4).

At each date, plots were assessed for plum rust incidence and severity. Incidence was measured as the mean proportion of leaves with foliar rust symptoms. Severity was measured as the percentage leaf area with rust, and a score given; 0 = <1%, 1 = 1-10%, 2 = 10-40%, and 3 = >40% leaf surface covered, respectively. On the final assessment date, percentage defoliation (%) was also recorded, and confirmed by the leaf scars left behind after abscission.

Phytotoxicity was recorded per individual tree using the following scale (Table 3).

**Table 3**. 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% trees affected |
| 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 |

**Table 4.** *T. discolor* disease and crop safety assessment schedule

| Evaluation date | Evaluation Timing (DA)* | Crop Growth Stage (BBCH) | Evaluation type (efficacy, phytotoxicity) | Assessment |
|---|---|---|---|---|
| 30/07/19 | -13 | 72 | Preliminary | - Rust incidence and severity |
| 12/08/19 | 0 | 79 | Efficacy<br>Phytotoxicity | - Rust incidence and severity<br>- Crop safety |
| 28/08/19 | 16 | 87 | Efficacy<br>Phytotoxicity | - Rust incidence and severity<br>- Crop safety |

| | | | | |
|---|---|---|---|---|
| 12/09/19 | 31 | 91 | Efficacy<br>Phytotoxicity | - Rust incidence and severity<br>- Crop safety |
| 26/09/19 | 45 | 91 | Efficacy<br>Phytotoxicity | - Rust incidence and severity<br>- Crop safety |
| 09/10/19 | 58 | 92 | Efficacy<br>Phytotoxicity | - Rust incidence and severity<br>- Crop safety |
| 31/10/19 | 80 | 92 | Efficacy | - Rust incidence and severity |

* DA – days after first *T. discolor* rust pustules emerged in trial area.

## Statistical analysis

The trial was analysed by Chris Dyer (ADAS statistician) as a randomised block design with six replicates of 8 treatments using ANOVA (Genstat 18th edition) and Abbott's Formula. No data transformation was required.

## Results

### Phytotoxicity

All test treatments, including the industry standard Amistar, had no phytotoxic effects (Table 5), with all plots scoring 10 (no damage). At no assessment date was the level of phytotoxicity therefore considered of commercial concern.

**Table 5**. Phytotoxicity scores for six assessment dates after treatment with test products.

| Date / Treatment | 12-Aug | 28-Aug | 12-Sept | 26-Sept | 09-Oct | 31-Oct |
|---|---|---|---|---|---|---|
| Untreated | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Amistar | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| AHDB 9851 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| AHDB 9911 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| AHDB 9957 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| AHDB 9872 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| AHDB 9885 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| AHDB 9852 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |

### Efficacy

*Incidence*: An even spread of rust infection was observed throughout the trial area, with a rapid increase in disease occurring after mid-September. Mid-way through the season, once the disease started to progress, a higher incidence of *T. discolor* occurred on the untreated control plots than in those treated with AHDB 9872, AHDB 9852 and Amistar (Table 6). By the final disease assessment, Amistar, AHDB 9851, AHDB 9911, AHDB 9957 and AHDB 9852 all significantly reduced rust incidence compared with the untreated control, with AHDB 9851 resulting in incidence below 2% for the entire duration of the trial, compared to the untreated control where final incidence was 94.2% (Appendix C, Image 5). AHDB 9872 resulted in a significantly higher incidence of disease at one assessment date (28-Aug) compared to the untreated control (Figure 2).

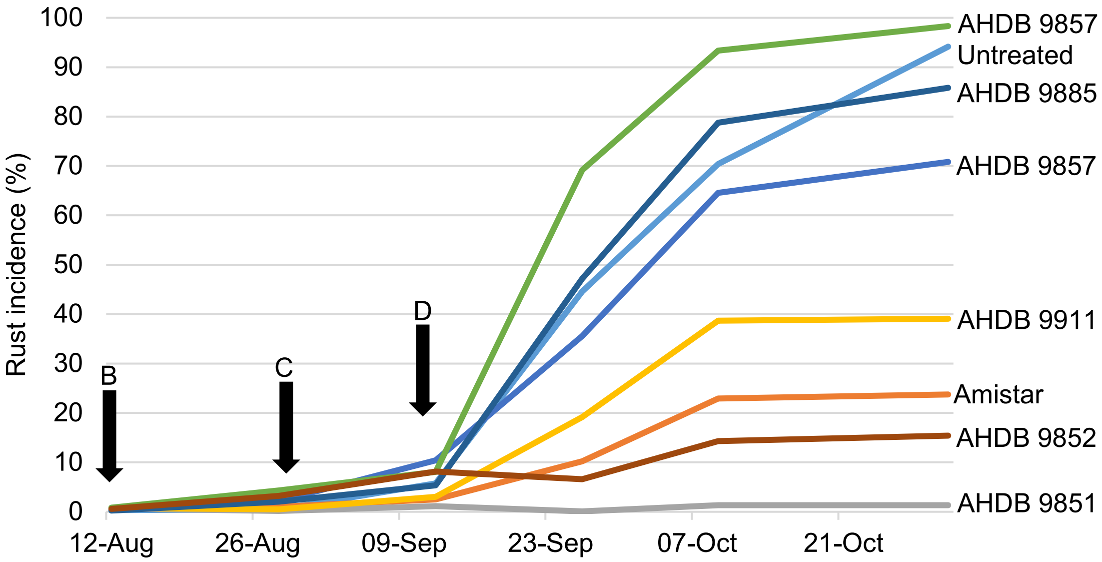



**Figure 1**. Effect of different products on incidence of plum rust at each assessment date. Black arrows indicate spray applications B, C, and D applied on 12 August, 28 August and 12 September 2019, respectively.

Following the first observations of rust in the trial on the 12 August, initial disease development was slow and it was not until mid-September before the disease began to spread rapidly (Figure 1) which corresponded with higher rainfall and cooler day time temperatures (Appendix D). The slow initial disease progression, resulted in applications A and B being applied as protective treatments, and C and D as curative applications. The AHDB 9851 treatment resulted in very effective control of *T. discolor* for the entire season (Fig. 1; Appendix C, image 7), with AHDB 9852 also performing well and better than the industry standard (Amistar).

**Table 6**. Effect of treatments on mean plum rust incidence (% of whole canopy per plot affected) for each of six assessment dates.

| Date / Treatment | 12-Aug | 28-Aug | 12-Sept | 26-Sept | 09-Oct | 31-Oct |
|---|---|---|---|---|---|---|
| Untreated | 0.3 | 0.5 | 5.8 | 44.6 | 70.4 | 94.2 |
| Amistar | 0.5 | 1.0 | 2.5 | 10.3 | 22.9 | 23.8 |
| AHDB 9851 | 0.7 | 0.2 | 1.2 | 0.1 | 1.3 | 1.3 |
| AHDB 9911 | 0.8 | 0.5 | 3.0 | 19.2 | 38.7 | 39.1 |
| AHDB 9957 | 0.4 | 2.2 | 10.4 | 35.6 | 64.6 | 70.8 |
| AHDB 9872 | 0.8 | 4.3 | 8.1 | 69.2 | 93.3 | 98.3 |
| AHDB 9885 | 0.3 | 2.1 | 5.3 | 47.2 | 78.8 | 85.8 |
| AHDB 9852 | 0.6 | 3.3 | 8.2 | 6.6 | 14.3 | 15.4 |
| P value | 0.776 | 0.081 | 0.096 | <0.001 | <0.001 | <0.001 |
| d.f. | 7 | 7 | 7 | 7 | 7 | 7 |
| s.e.d. | 0.3827 | 1.478 | 3.275 | 9.680 | 10.500 | 9.860 |
| l.s.d. | 0.78 | 3.00 | 6.65 | 19.25 | 20.89 | 19.16 |
| (blue) | Not significantly different from untreated control (p>0.05) | | | | | |
| (peach) | Significantly less than untreated control (p<0.05) | | | | | |
| (white) | Significantly more than untreated control (p<0.05) | | | | | |

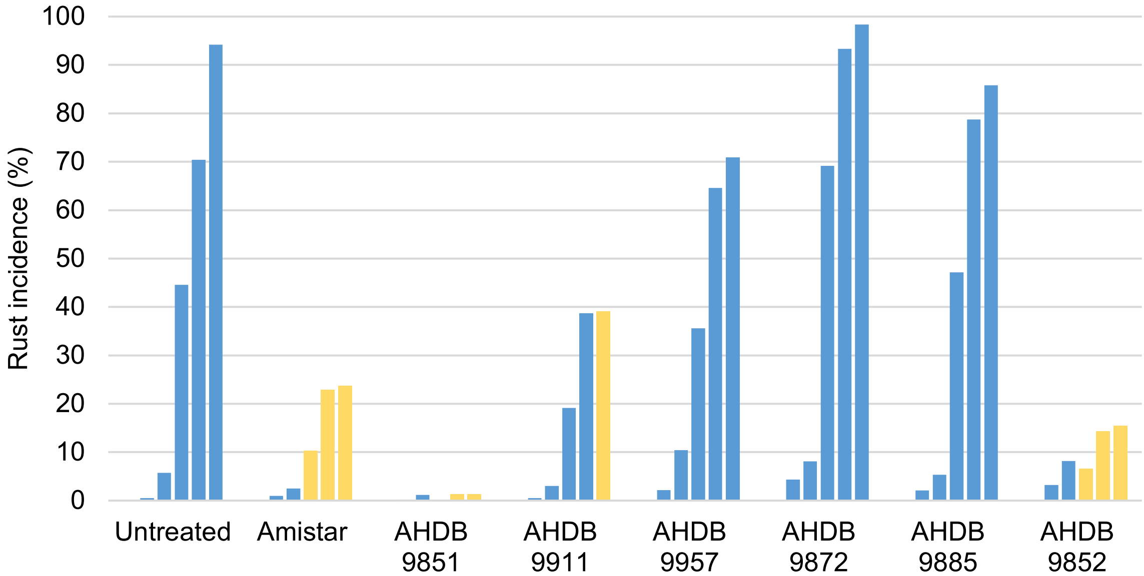



**Figure 2**. Effect of fungicide treatments on incidence of plum rust (*T. discolor*) across five assessments dates, 28 August, 12 September, 26 September, 09 October and 31 October respectively. Yellow bars indicate significant reduction in disease compared to untreated control at the respective dates.

*Severity*: On 26 September (45 days after first rust observation) the AHDB 9851 treatment resulted in a significantly lower disease severity than the untreated control (Table 7). By the final assessment (31 October), AHDB 9911 and AHDB 9852, and Amistar also resulted in a significantly lower severity than the untreated control. Both AHDB 9851 and AHDB 9852 reduced the average disease severity under a score of 1 (1-10% leaf surface area with rust) for the entire season. As leaf surface covered in rust exceeded 40%, many leaves began to abscise. As the severity of rust symptoms could only be assessed by scoring the leaves left on the tree, this detail should be considered when judging the average severity scores together with the proportion of early defoliation, assessed on 31 October (Figure 3).

**Table 7**. Effect of fungicide treatments on mean *T. discolor* severity score (0 = <1%, 1 = 1-10%, 2 = 11-40%, and 3 = >40% leaf surface covered) at three of the six disease assessment dates. Severity was zero across entire trial at the preliminary assessment on 30 July 2019.

| Date / Treatment | 12-Aug* | 28-Aug* | 12-Sept* | 26-Sept | 09-Oct | 31-Oct |
|---|---|---|---|---|---|---|
| Untreated | 0.0 | 0.0 | 0.0 | 1.6 | 1.8 | 2.0 |
| Amistar | 0.0 | 0.0 | 0.0 | 0.8 | 0.8 | 1.1 |
| AHDB 9851 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 |
| AHDB 9911 | 0.0 | 0.0 | 0.0 | 1.2 | 1.0 | 1.2 |
| AHDB 9957 | 0.0 | 0.0 | 0.0 | 1.7 | 1.7 | 2.2 |
| AHDB 9872 | 0.0 | 0.0 | 0.0 | 2.3 | 2.3 | 2.2 |
| AHDB 9885 | 0.0 | 0.0 | 0.0 | 1.8 | 1.8 | 2.2 |
| AHDB 9852 | 0.0 | 0.0 | 0.0 | 0.9 | 0.8 | 0.9 |
| P value | - | - | - | <0.001 | <0.001 | <0.001 |
| d.f. | - | - | - | 7 | 7 | 7 |
| s.e.d. | - | - | - | 0.427 | 0.3342 | 0.3852 |
| l.s.d. | - | - | - | 0.867 | 0.6784 | 0.7820 |
| (blue) | Not significantly different from untreated control (p>0.05) | | | | | |
| (peach) | Significantly less than untreated control (p<0.05) | | | | | |

* Disease levels not high enough to give accurate severity score at this date.

A single assessment was made at the end of the trial (31 October) to measure defoliation, at a time when rust-free plum trees would all still have green, healthy leaves. Premature defoliation was observed in the untreated control plots, as well as those treated with AHDB 9957, AHDB 9972 and AHDB 9985 (Figure 3). In contrast, no defoliation occurred on trees treated with AHDB 9851 nor the industry standard (Amistar), which, as well as AHDB 9852 and AHDB 9911 all had significantly less defoliation than the untreated control.

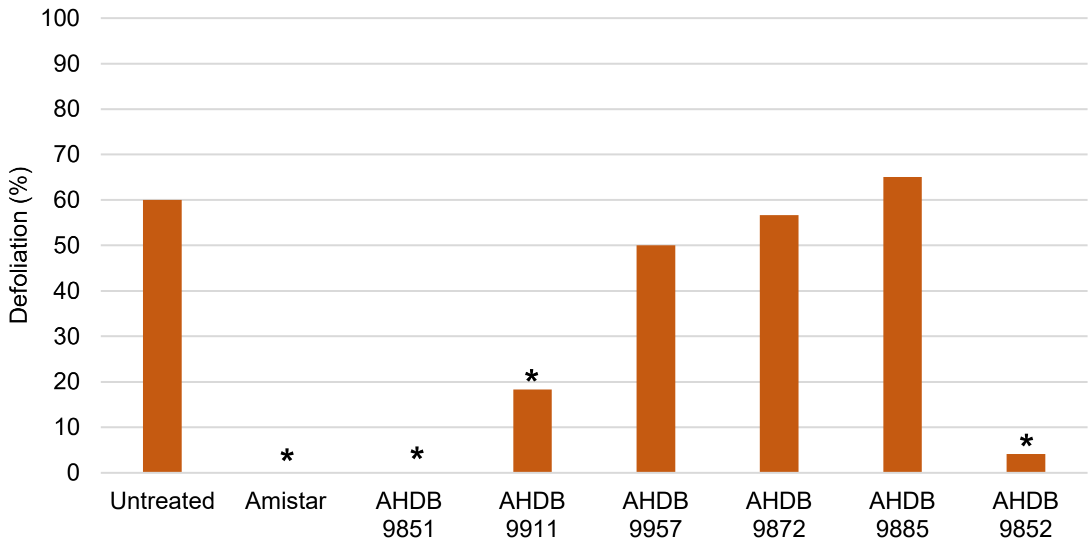



**Figure 3**. Defoliation of plum trees infected with *T. discolor* at final assessment on 31 October 2019. Asterisks indicate products that resulted in significantly less defoliation than the untreated control (p = <0.01).

Proportional reductions (%) in disease incidence for each treatment compared with the untreated control at each assessment date (Table 9). By the final assessment, AHDB 9851 had reduced plum rust incidence by 98.6%, AHDB 9852 by 83.6%, and the industry standard (Amistar) by 74.8%, respectively. This was in line with the lack of premature defoliation seen on Amistar and AHDB 9851, and the low percentage seen by AHDB 9852.

**Table 8**. Mean incidence of *T. discolor* per treatment as a proportional reduction (%) of the untreated score (Abbott's formula) following each treatment application

| Date / Treatment | 12-Aug* | 28-Aug* | 12-Sep | 26-Sep | 09-Oct | 31-Oct |
|---|---|---|---|---|---|---|
| Untreated | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Amistar | -50.0 | -100.0 | 56.5 | **77.0** | **67.5** | **74.8** |
| AHDB 9851 | -100.0 | 66.7 | 79.7 | **99.8** | **98.1** | **98.6** |
| AHDB 9911 | -125.0 | 0.0 | 47.8 | 57.0 | 45.1 | **58.5** |
| AHDB 9957 | -25.0 | -333.3 | -81.2 | 20.2 | 8.3 | 24.8 |
| AHDB 9872 | -150.0 | -766.7 | -40.6 | -55.1 | -32.5 | -4.4 |
| AHDB 9885 | 25.0 | -316.7 | 7.2 | -5.8 | -11.8 | 8.8 |
| AHDB 9852 | -75.0 | -550.0 | -42.0 | **85.2** | **79.6** | **83.6** |

Values in bold correspond to results which are significantly less than the untreated control ($p<0.05$).
*Incidence of *T. discolor* was very low at the first two assessment dates, never appearing on more than 5% of the whole canopy, so small differences between the untreated control and treatments, appear significant, when in actuality they were minor.

# Discussion

The trial area was successfully infected via airborne spores of *T. discolor* released from a nearby mature plum orchard. Disease progression was initially slower than generally observed by growers, but nonetheless there was rapid development of rust pustules in mid-September (rather than mid-August as is usual), most likely due to late summer rain, as leaf wetness is required for *T. discolor* infection. Untreated control plants had 5.8% of whole canopy infected on 12 September, which increased to 44.6% two weeks later, and to 94.2% by the end of the trial on 31 October. The timings of all four spray applications overlapped with the usual time for plum harvest, and so the harvest intervals of the tested products would need to be considered in the future. By the end of the trial (31 October 2019), many untreated control trees were completely defoliated due to *T. discolor* infection (Appendix C, image 7). Where *T. discolor* had not been able to establish or infect leaves to such an extent, premature defoliation was reduced, and in some cases, did not occur at all, as seen for plots treated with AHDB 9851, and the industry standard Amistar.

Throughout the trial, two products resulted in lower rust disease levels than the industry standard Amistar; AHDB 9851 and AHDB 9852. AHDB 9851 (FRAC 11) prevented any significant establishment of *T. discolor*, with almost every leaf on the young plum trees remaining healthy and vigorous by the end of the trial, while, in contrast, the untreated control trees suffered an average of 60% defoliation. With AHDB 9851 showing such good efficacy, this product may be able to provide adequate control with fewer than the four applications used in this study. However, it still belongs to the same FRAC group as the industry standard Amistar, so it would need careful consideration as part of an integrated management programme. Nonetheless, it was superior to all the other treatments, and enabled a highly susceptible plum cultivar to remain disease free for the entire growing season. This product should be considered in further work on other *Puccinia* rust diseases in horticultural crops.

AHDB 9852 (FRAC BM 01) also resulted in significant rust control compared to the untreated, with incidence of rust below 20% throughout the season. Furthermore, It was noticed on 12 September 2019 that whilst AHDB 9852 treated plots still had yellow uredia, no teliospores (resting spores) were present (Appendix C, image 6) in contrast to the untreated control plants (Appendix c, image 4). The same observation was noted at the next assessment on the 26 September but teliospores were eventually observed on AHDB 9852 treatments on 09 October 2019. This suggests that this product can reduce and delay teliospore production or may affect fungal activity on the surface of the leaf, to slow the formation of telia. The trigger for *T. discolor* to switch from uredia production, to telia production is unknown but in other rust species is thought to be due to environmental cues such as decreasing temperatures. Reducing the volume of teliospores towards the end of the season may be beneficial, as fewer are then able to overwinter and potentially reinfect trees the next season. AHDB 9852 is a plant extract, and has a very short harvest interval and so could be used to maintain control as fruits mature. It could also be a useful component in organic production.

Although not as effective as the industry standard Amistar, AHDB 9911 also resulted in significant control of plum rust, with a 58.5% reduction in incidence compared to the untreated control at the final assessment. The active is an SDHI (FRAC 7) and may therefore be useful to include as part of a fungicide-resistance management programme alongside Amistar (FRAC 11).

Plots treated with AHDB 9872 resulted in a significantly higher incidence of rust than the untreated control at one assessment date (28 August), and consistently had the highest levels of rust at each assessment date thereafter. The active in AHDB 9872 has known efficacy against powdery mildews, Botrytis and other ascomycete fungal pathogens. However, *T. discolor* is a basidiomycete which could explain the lack of efficacy.

Rust severity scores followed a similar pattern to rust incidence, whereby AHDB 9851, AHDB 9911 and AHDB 9852 all significantly reduced the disease severity compared to the untreated control, as did Amistar. It should be noted however that the severity of rust symptoms could only be assessed for those leaves left on the tree. By 31 October, severe defoliation had taken place, so a tree that may have scored 3 (>40% leaf surface area covered) mid-season, could score 2 (11-40% leaf surface area covered) by the end of the trial, where the only leaves that are left, are those that were infected later on in the season, and so were not so badly affected by rust pustules. However, the disease severity scores still highlight treatments that slowed down or halted rust progression, in particular, AHDB 9851 and AHDB 9852, which resulted in consistent, low rust severity throughout the trial.

No phytotoxicity was noted at any assessment date, indicating that all experimental treatments were crop safe, but crop exposure needs to be considered when putting any product through for EAMU (Extension of Authorisation for Minor Use).

# Conclusions

- Four of the test products significantly reduced plum rust incidence and/or severity compared to the untreated controls at the final disease assessment date.
- Product AHDB 9851 gave significantly better rust control than the untreated control at every assessment, and performed better than the industry standard at the final assessment date.
- The biological product AHDB 9852 resulted in a lower incidence of rust than the untreated controls on the final three disease assessments.
- Product AHDB 9872 increased incidence of disease at one assessment date, compared to the untreated control, suggesting no efficacy towards *T. discolor* on plum.
- Further work is required to establish the best integrated programmes incorporating the most effective products identified in this work, whilst taking harvest intervals into careful consideration.
- No symptoms associated with phytotoxicity developed on any plants, at any date.

# Acknowledgements

I would like to thank Chris Dyer for performing the statistical analysis, and AHDB Horticulture and participating crop protection companies for advice on product selection and use, and for supporting the SCEPTREplus program.

Special thanks to Robert & Stuart Norman for hosting the trial.

# Appendix

## a. Crop diary

Species – Plum
Cultivar – Victoria
Planted – April 2019

Cultivations, fertalisers, etc. – The trial was cultivated following normal commercial practices. No chemical insecticides or fungicides were applied, outside of those included in the trial programme.

Trees were first year maidens, so the few fruit that did form were picked when ripe, and removed, to get rid of potential resources for insect pests.

**Fertaliser inputs to trial area**

| Date | Product | Rate |
|---|---|---|
| One dose to trees straight after planting. | Nutrigrow Growmore 7-7-7 | 100g per $m^2$ |

## b. Trial Diary

| Date | Event |
|---|---|
| 16/04/2019 | Bare root cv. Victoria trees delivered from cold store to grower's orchard, and planted immediately. Plant feed applied. |
| 18/04/2019 | Drip irrigation lines set-up in trial area, to ensure young plants watered sufficiently. |
| 30/07/2019 | - Treatment application 1<br>- Preliminary assessment |
| 12/08/2019 | First rust symptoms appear in trial area. |
| 12/08/2019 | - Disease assessment 1<br>- Phytotoxicity assessment 1<br>- Treatment application 2 |
| 28/08/2019 | - Disease assessment 2<br>- Phytotoxicity assessment 2<br>- Treatment application 3 |
| 12/09/2019 | - Disease assessment 3<br>- Phytotoxicity assessment 3<br>- Treatment application 4 |
| 26/09/2019 | - Disease assessment 4<br>- Phytotoxicity assessment 4 |
| 09/10/2019 | - Disease assessment 5<br>- Phytotoxicity assessment 5 |
| 31/10/2019 | - Disease assessment 6<br>- Phytotoxicity assessment 6 |

### c. Experiment images

**Image 1**. Bud-break (07 May 2019). Mypex ground mulch to prevent weeds and protect irrigation lines. Plastic sheath around bottom of young trees to prevent rabbit damage.

**Image 2**. Plastic sheet used to encircle trees in plot, to prevent spray drift during application. Plastic sheeting was washed thoroughly between each treatment. Tree in image was subsequently pruned down to 1.8m, to make sure entire tree canopy received treatment.

**Image 3.** First rust symptoms observed 12 August 2019, Cambridgeshire, UK. Yellow specks (left) on leaf upper side, orange/brown urediospores on leaf underside (right).

**Image 4.** Yellow speckling on leaf upper surface (left) and black pustules (telia) containing teliospores on leaf underside (right), on untreated control on 26 September 2019.

**Image 5**. Very low rust incidence on trees treated with AHDB 9851 (left) compared to the untreated control (right) during assessment 26 September 2019.

**Image 6**. Typical yellow speckling on leaf upper surface (left) but an absence of black telia on leaf underside (right) on trees treated with AHDB 9852, observed on 12 September 2019.

**Image 7**. Premature defoliation caused by *T. discolor* on untreated plum trees (top left + right) compared to those treated with AHDB 9851 (bottom left + right) on 31 October 2019.

**Image 8**. Different levels of defoliation amongst plum trees on 31 October 2019.

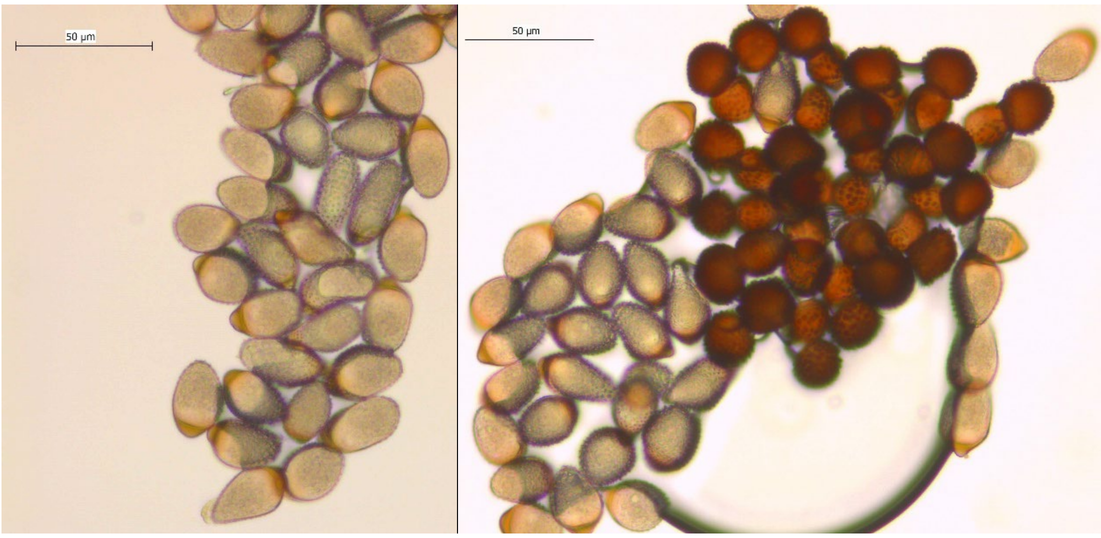
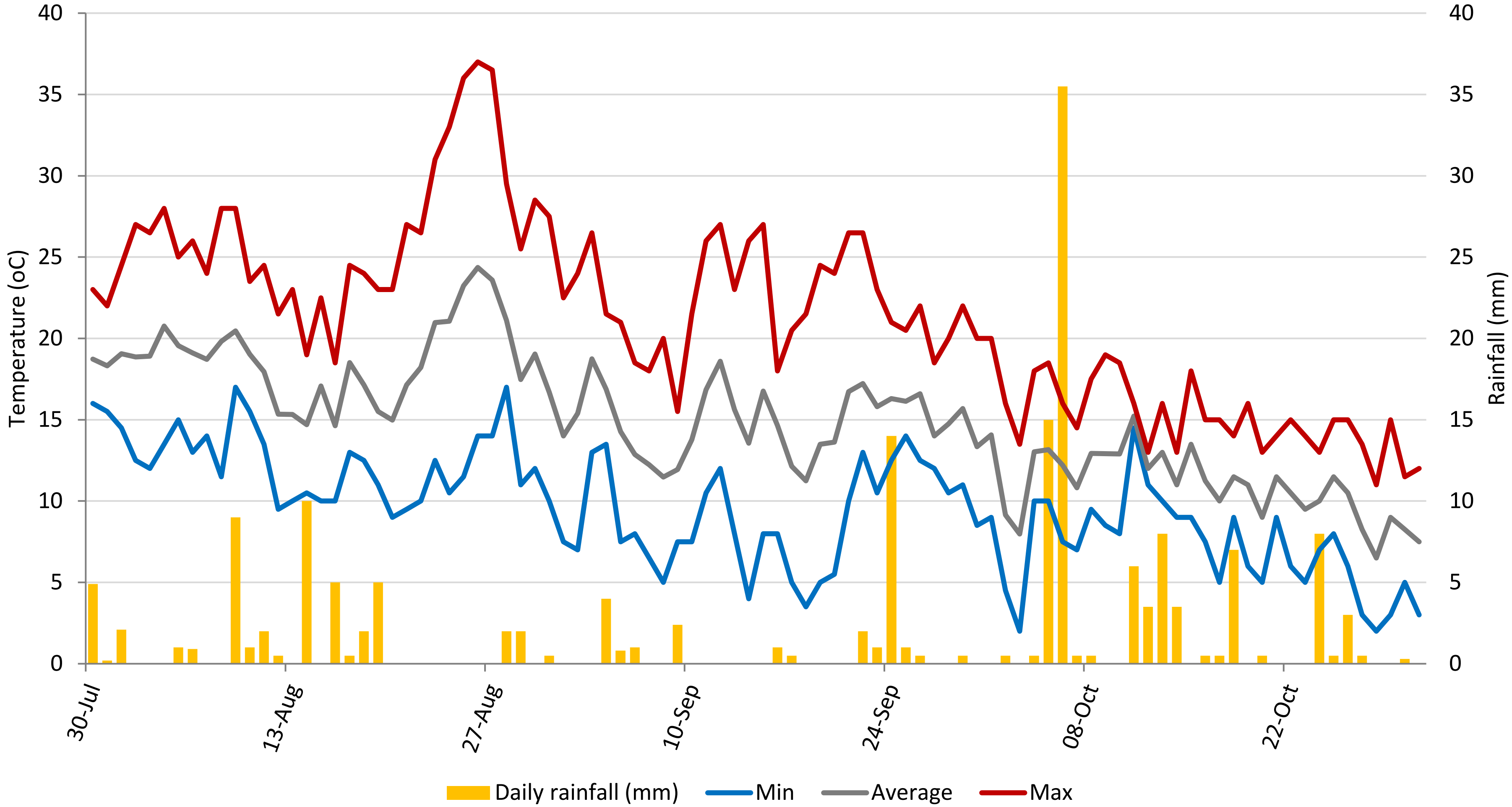



**Image 9**.*Tranzschelia discolor* urediospores (left), and a group of urediospores and teliospores (right).

d. Climatological data during study period (30/07/19 – 31/10/19)

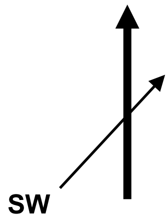


e. Raw data from assessments (12.08.19 – 31.10.19)

| | | | **Incidence (%), severity (score 0-3) and defoliation (%) of plum trees infected with *Tranzschelia discolor*** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **12- Aug** | | **28-Aug** | | **12-Sep** | | **26-Sep** | | **09-Oct** | | **31-Oct** | | |
| **Block** | **Plot** | **Treatment** | Incidence | Severity | Incidence | Severity | Incidence | Severity | Incidence | Severity | Incidence | Severity | Incidence | Severity | Defoliation |
| 1 | 1 | 6 | 1.00 | 5.0 | 7.5 | 60.0 | 2.0 | 65.0 | 2.0 | 100.0 | 1.5 | 1.00 | 5.0 | 7.5 | 50 |
| 1 | 2 | 5 | 0.00 | 1.0 | 3.5 | 1.0 | 1.0 | 7.5 | 1.0 | 25.0 | 1.0 | 0.00 | 1.0 | 3.5 | 0 |
| 1 | 3 | 1 | 0.00 | 1.0 | 3.5 | 35.0 | 1.0 | 55.0 | 1.5 | 100.0 | 1.0 | 0.00 | 1.0 | 3.5 | 70 |
| 1 | 4 | 7 | 0.00 | 0.0 | 7.5 | 15.0 | 1.0 | 60.0 | 2.0 | 80.0 | 1.0 | 0.00 | 0.0 | 7.5 | 50 |
| 1 | 5 | 2 | 1.00 | 1.0 | 3.5 | 35.0 | 2.0 | 37.5 | 1.5 | 37.5 | 1.5 | 1.00 | 1.0 | 3.5 | 0 |
| 1 | 6 | 8 | 0.00 | 0.0 | 1.0 | 1.0 | 1.0 | 10.0 | 1.0 | 15.0 | 1.0 | 0.00 | 0.0 | 1.0 | 15 |
| 1 | 7 | 4 | 0.50 | 0.0 | 0.5 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.50 | 0.0 | 0.5 | 0 |
| 1 | 8 | 3 | 1.00 | 0.0 | 1.5 | 0.5 | 0.5 | 5.0 | 1.0 | 5.0 | 1.0 | 1.00 | 0.0 | 1.5 | 0 |
| 2 | 9 | 4 | 0.00 | 0.0 | 1.5 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.00 | 0.0 | 1.5 | 0 |
| 2 | 10 | 1 | 0.00 | 0.0 | 1.0 | 5.0 | 1.0 | 22.5 | 1.5 | 100.0 | 2.0 | 0.00 | 0.0 | 1.0 | 30 |
| 2 | 11 | 6 | 1.00 | 10.0 | 10.0 | 82.5 | 2.5 | 100.0 | 3.0 | 90.0 | 2.5 | 1.00 | 10.0 | 10.0 | 60 |
| 2 | 12 | 5 | 1.00 | 10.0 | 20.0 | 35.0 | 2.0 | 55.0 | 2.0 | 55.0 | 2.0 | 1.00 | 10.0 | 20.0 | 50 |
| 2 | 13 | 8 | 0.00 | 1.0 | 5.0 | 7.5 | 1.0 | 3.5 | 0.5 | 5.0 | 1.0 | 0.00 | 1.0 | 5.0 | 0 |
| 2 | 14 | 3 | 0.50 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.50 | 0.0 | 0.0 | 0 |
| 2 | 15 | 7 | 0.00 | 5.0 | 5.0 | 55.0 | 2.0 | 100.0 | 2.0 | 100.0 | 2.5 | 0.00 | 5.0 | 5.0 | 70 |
| 2 | 16 | 2 | 1.00 | 5.0 | 4.0 | 20.0 | 1.0 | 60.0 | 1.0 | 60.0 | 1.0 | 1.00 | 5.0 | 4.0 | 0 |
| 3 | 17 | 3 | 0.00 | 1.0 | 1.0 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.00 | 1.0 | 1.0 | 0 |
| 3 | 18 | 5 | 1.00 | 0.0 | 1.5 | 7.5 | 1.0 | 40.0 | 1.5 | 45.0 | 1.5 | 1.00 | 0.0 | 1.5 | 10 |
| 3 | 19 | 8 | 0.00 | 1.0 | 3.0 | 1.0 | 1.0 | 12.5 | 1.0 | 12.5 | 1.0 | 0.00 | 1.0 | 3.0 | 0 |
| 3 | 20 | 6 | 0.00 | 1.0 | 2.5 | 75.0 | 2.5 | 100.0 | 2.0 | 100.0 | 2.5 | 0.00 | 1.0 | 2.5 | 80 |
| 3 | 21 | 1 | 0.00 | 1.0 | 3.5 | 55.0 | 2.0 | 95.0 | 2.0 | 100.0 | 2.5 | 0.00 | 1.0 | 3.5 | 90 |
| 3 | 22 | 7 | 0.50 | 1.0 | 5.0 | 85.0 | 2.5 | 100.0 | 2.0 | 100.0 | 3.0 | 0.50 | 1.0 | 5.0 | 90 |
| 3 | 23 | 2 | 1.00 | 0.0 | 1.0 | 1.0 | 1.0 | 10.0 | 1.0 | 10.0 | 1.0 | 1.00 | 0.0 | 1.0 | 0 |
| 3 | 24 | 4 | 1.00 | 1.0 | 2.0 | 10.0 | 1.0 | 15.0 | 1.0 | 12.5 | 1.0 | 1.00 | 1.0 | 2.0 | 0 |
| 4 | 25 | 6 | 1.50 | 5.0 | 7.5 | 50.0 | 2.5 | 100.0 | 2.0 | 100.0 | 1.0 | 1.50 | 5.0 | 7.5 | 40 |
| 4 | 26 | 1 | 1.50 | 0.0 | 2.5 | 70.0 | 2.0 | 85.0 | 2.0 | 100.0 | 2.0 | 1.50 | 0.0 | 2.5 | 70 |
| 4 | 27 | 5 | 0.50 | 1.0 | 20.0 | 70.0 | 2.5 | 100.0 | 2.0 | 100.0 | 3.0 | 0.50 | 1.0 | 20.0 | 70 |
| 4 | 28 | 8 | 1.00 | 7.5 | 17.5 | 12.5 | 1.0 | 35.0 | 1.0 | 35.0 | 1.0 | 1.00 | 7.5 | 17.5 | 0 |
| 4 | 29 | 4 | 2.50 | 1.0 | 5.0 | 15.0 | 2.0 | 20.0 | 1.0 | 20.0 | 2.0 | 2.50 | 1.0 | 5.0 | 10 |
| 4 | 30 | 2 | 0.00 | 0.0 | 1.0 | 0.0 | 0.0 | 12.5 | 1.0 | 17.5 | 2.0 | 0.00 | 0.0 | 1.0 | 0 |
| 4 | 31 | 7 | 0.00 | 0.5 | 4.0 | 55.0 | 2.5 | 80.0 | 2.0 | 100.0 | 2.5 | 0.00 | 0.5 | 4.0 | 80 |
| 4 | 32 | 3 | 0.50 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.50 | 0.0 | 0.0 | 0 |
| 5 | 33 | 7 | 0.00 | 1.0 | 3.0 | 3.0 | 1.0 | 35.0 | 1.0 | 35.0 | 1.0 | 0.00 | 1.0 | 3.0 | 10 |
| 5 | 34 | 8 | 2.50 | 10.0 | 22.5 | 17.5 | 1.5 | 25.0 | 1.5 | 25.0 | 1.5 | 2.50 | 10.0 | 22.5 | 10 |
| 5 | 35 | 3 | 1.00 | 0.0 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.00 | 0.0 | 3.5 | 0 |
| 5 | 36 | 5 | 0.00 | 0.0 | 12.5 | 20.0 | 1.5 | 85.0 | 1.5 | 100.0 | 2.5 | 0.00 | 0.0 | 12.5 | 80 |
| 5 | 37 | 1 | 0.50 | 0.0 | 1.5 | 12.5 | 1.0 | 65.0 | 1.5 | 65.0 | 1.5 | 0.50 | 0.0 | 1.5 | 5 |
| 5 | 38 | 4 | 0.50 | 0.0 | 1.5 | 60.0 | 2.0 | 100.0 | 2.0 | 100.0 | 2.0 | 0.50 | 0.0 | 1.5 | 50 |
| 5 | 39 | 6 | 0.50 | 5.0 | 15.0 | 92.5 | 3.0 | 100.0 | 3.0 | 100.0 | 2.5 | 0.50 | 5.0 | 15.0 | 50 |
| 5 | 40 | 2 | 0.00 | 0.0 | 0.5 | 5.5 | 1.0 | 12.5 | 0.5 | 12.5 | 1.0 | 0.00 | 0.0 | 0.5 | 0 |
| 6 | 41 | 3 | 1.00 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.00 | 0.0 | 1.0 | 0 |
| 6 | 42 | 6 | 1.00 | 0.0 | 6.0 | 55.0 | 1.5 | 95.0 | 1.5 | 100.0 | 3.0 | 1.00 | 0.0 | 6.0 | 60 |
| 6 | 43 | 5 | 0.00 | 1.0 | 5.0 | 80.0 | 2.0 | 100.0 | 2.0 | 100.0 | 3.0 | 0.00 | 1.0 | 5.0 | 90 |
| 6 | 44 | 7 | 1.00 | 5.0 | 7.5 | 70.0 | 2.0 | 97.5 | 2.0 | 100.0 | 3.0 | 1.00 | 5.0 | 7.5 | 90 |
| 6 | 45 | 8 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0 |
| 6 | 46 | 2 | 0.00 | 0.0 | 5.0 | 0.0 | 0.0 | 5.0 | 0.0 | 5.0 | 0.0 | 0.00 | 0.0 | 5.0 | 0 |
| 6 | 47 | 4 | 0.00 | 1.0 | 7.5 | 30.0 | 2.0 | 95.0 | 2.0 | 100.0 | 2.0 | 0.00 | 1.0 | 7.5 | 50 |
| 6 | 48 | 1 | 0.00 | 1.0 | 22.5 | 90.0 | 2.5 | 100.0 | 2.5 | 100.0 | 3.0 | 0.00 | 1.0 | 22.5 | 95 |

f. Trial design

| Block | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plot** | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| | AHDB 9885 | AHDB 9851 | AHDB 9957 | Amistar | AHDB 9872 | AHDB 9911 | AHDB 9852 | AHDB 9851 | AHDB 9957 | Amistar | AHDB 9885 | **Control** |
| **Plot** | 3 | 7 | 11 | 15 | 19 | 23 | 27 | 31 | 35 | 39 | 43 | 47 |
| | **Control** | AHDB 9911 | AHDB 9872 | AHDB 9885 | AHDB 9852 | Amistar | AHDB 9957 | AHDB 9885 | AHDB 9851 | AHDB 9872 | AHDB 9957 | AHDB 9911 |
| **Plot** | 2 | 6 | 10 | 14 | 18 | 22 | 26 | 30 | 34 | 38 | 42 | 46 |
| | AHDB 9957 | AHDB 9852 | **Control** | AHDB 9851 | AHDB 9957 | AHDB 9885 | **Control** | Amistar | AHDB 9852 | AHDB 9911 | AHDB 9872 | Amistar |
| **Plot** | 1 | 5 | 9 | 13 | 17 | 21 | 25 | 29 | 33 | 37 | 41 | 45 |
| | AHDB 9872 | Amistar | AHDB 9911 | AHDB 9852 | AHDB 9851 | **Control** | AHDB 9872 | AHDB 9911 | AHDB 9885 | **Control** | AHDB 9851 | AHDB 9852 |




Wind direction

g. Pre-trial soil analysis (sample collected 24 April 2019)

| **Soil pH** | **mg/l (Available)** | | |
|---|---|---|---|
| | P | K | Mg |
| 5.8 | 65.4 | 282 | 78 |

h. ORETO Certificate

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**Effective date:** 18 March 2018
**Expiry date:** 17 March 2023

**Signature**
*Authorised signatory*

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