Project title:	Evaluation of products for control of *Neonectria ditissima* on apples
Project number:	TF 216
Project leader:	Dr Angela M Berrie, East Malling Research
Report:	Annual report, May 2015
Previous report:	None
Key staff:	Dr Angela M Berrie Dr Robert Saville
Location of project:	East Malling Research
Industry Representative:	Mark Holden, Adrian Scripps Ltd, Whetsted Road, Five Oak Green, Tonbridge, Kent TN12 6RR
Date project commenced:	01 April 2014
Date project completed (or expected completion date):	30 June 2016

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

AUTHENTICATION

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

Dr Angela M Berrie

Senior Research Leader

East Malling Research 22 May 2015

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

Dr Robert Saville

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East Malling Research 22 May 2015

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GROWER SUMMARY

Headline

- Syllit 400SC (dodine) and two experimental fungicides reduced *Neonectria* fruit rot by around 50% when applied as two sprays at petal fall and two pre-harvest.

Background and expected deliverables

Canker, caused by the fungus *Nectria galligena* (now renamed as *Neonectria ditissima*), is one of the most important diseases of apple and pear. Most of the established apple cultivars are very susceptible to the disease and the more recently introduced cultivars such as Jazz, Braeburn, Reubens, Cameo, Kanzi and Zari are also particularly susceptible. The fungus attacks trees in the orchard, causing cankers and die back of young shoots, resulting in loss of fruiting wood and increasing pruning costs. Apple canker can be particularly damaging in young orchards where, in some years, up to 10% of trees can be lost annually in the first few years of orchard establishment, as a result of trunk cankers, particularly following exceptionally wet or cold winters. *N ditissima* also causes a fruit rot that can result in significant losses as high as 10% or more in stored fruit. *Neonectria* rot, which is often at the fruit stalk end, is also difficult to spot on the grading line, but becomes obvious during marketing leading to rejection of fruit consignments.

In 2013 the incidence of canker in apple orchards was exceptionally high as a result of wet weather during leaf fall in 2011 and 2012 and above average rainfall in spring and summer 2012. Of particular significance was the high incidence of trees with systemic canker in young orchards which is most likely to have arisen from the tree nursery. This is especially important given that many growers are investing in new orchards with cultivars that are particularly susceptible and / or sensitive to canker so the problem will only get worse.

Much is known about the epidemiology of apple canker but there are still significant gaps in knowledge which will require long term research and are now being addressed in the new AHDB Horticulture project TF223 (*Integrated pest management of tree fruit pests and* diseases) which started in April 2015. However, in the short term, control of the cankers and fruit rot is still very dependent on fungicide sprays and, even when new approaches are developed and implemented, it is likely that fungicides will still play an important role in the integrated approach.

Canker is controlled in commercial farms by a combination of cultural methods to remove canker lesions and the use of protectant fungicides. Effective fungicides are currently limited. Generally, copper fungicides are used at autumn leaf fall and before budburst to protect leaf scars and bud-scale scars. Previously, products based on carbendazim were applied during the spring and summer to prevent tree and fruit infection in this period. These products are no longer approved for use. In AHDB Horticulture project TF144, potential alternative fungicides were evaluated for canker control and tebuconazole (Folicur) was identified as a possible alternative product and now has an EAMU (0115/2015) for use post-harvest during leaf fall. However, products effective against *N. ditissima* that can be used in the growing season are limited. There is now a range of fungicides from new chemical groups (SDHI group), foliar nutrients and fortifying products and biocontrol agents that could potentially be active against *N. ditissima* which are worth evaluating.

Summary of the project and main conclusions

In this project experimental fungicides, alternative chemicals and a biocontrol agent were evaluated for their efficacy in controlling *Neonectria* canker and fruit rot. Two separate trials were conducted on cv. Gala at East Malling Research in 2014.

In the fruit rot trial, six experimental fungicides, Syllit 400SC (dodine), two alternative chemicals and the biocontrol agent Serenade ASO (*Bacillus subtilis*) were compared to Bellis (pyraclostrobin + boscalid) and an untreated control for control of *Neonectria* fruit rot. Fungicides were applied twice at petal fall and twice pre-harvest, while the other products were applied every two weeks from petal fall. Fruit was harvested in September and cold-stored in controlled atmosphere conditions until March when fruit rot incidence was assessed.

Weather conditions at petal fall and pre-harvest were favourable for infection of fruit by *N. ditissima* with around 10% fruit rot in untreated plots. Two experimental products HDC F115 and HDC F119 and one existing registered product Syllit 400SC significantly reduced *Neonectria* fruit rot by up to 50%. Treatments HDC F120, CuPC33 and 42Phi Cu showed reductions in rot incidence but were not statistically significant. Treatments HDC F115, Syllit 400SC and HDC F120 also significantly reduced the incidence of brown rot. The incidence of fruit scab was significantly less on fruit treated with HDC F115, HDC F118, HDC F119, Syllit 400SC, HDC F120, HDC F121 and CuPC33 compared to the untreated control. Syllit 400SC was significantly better than all other treatments.

In the canker control trial similar products were evaluated with Folicur (tebuconazole) included as the standard. Products were applied four times at 10%, 50%, 90% and 100% leaf fall. The trial will be assessed for leaf scar cankers in June. In a separate study, sodium hypochlorite (14% chlorine) was compared to Folicur (tebuconazole) and an untreated control for its ability to suppress *N. ditissima* cankers on apple trees when applied as a drenching spray. The efficacy of the treatments was assessed by collecting canker washings and checking them under the microscope for *N. ditissima* spores. The trial was set up in January 2015. Unfortunately, none of the cankers targeted produced any spores, even the untreated ones. It appeared that many of the cankers had become inactive following prolonged dry weather at this time. The trial will be repeated in December 2015.

Financial benefits

Many new orchards are planted as intensive fruit wall systems (c. 3000 trees/ha) to maximise yield and quality and simplify management and harvesting. Establishment costs are expensive at £7/tree or £21,000/ha, so tree losses in the early years of the orchard can be particularly damaging financially. *N. ditissima* also causes a fruit rot that can result in significant losses as high as 10% or more in stored fruit. Rots often occur in the stalk end of the fruit and are difficult to detect during fruit grading and subsequently develop during marketing leading to the rejection of fruit consignments. Orchards receive routine sprays of fungicides pre and post-harvest to protect trees and fruit from *Neonectria* fungal infection at an average annual cost of around £700/ha. Effective products available for use in the growing season are limited. This project is not going to solve the ‘canker problem’ completely but will identify new products that could be used in the growing season to protect fruit and the tree from *Neonectria* infection. This should result in better control of the disease and reduction in losses in the orchard and in store and contribute to the wider research on canker undertaken as part of the new AHDB Horticulture tree fruit project.

The information generated from the project will be delivered to the industry through AHDB grower and through joint EMRA / AHDB Horticulture grower days. In addition there may be opportunities to view trials. If appropriate, EAMUs would be sought for effective products identified.

Action points for growers

- This project has identified potential fungicide products that could be used to control *Neonectria* fruit rot.

- However, two of the products are experimental and will require registration or EAMUs before they can be used in practice.

- The third product Syllit is registered for use on apples and pears but for dessert apples only pre-blossom and for culinary apples up to July.

SCIENCE SECTION

Introduction

Canker, caused by the fungus *Neonectria ditissima* (previously named *Nectria galligena*), is one of the most important diseases of apple and pear. Most of the established apple cultivars are very susceptible to the disease and the more recently introduced cultivars such as 'Jazz', 'Braeburn', 'Reubens', 'Cameo', 'Kanzi' and 'Zari' are also particularly susceptible. The fungus attacks trees in the orchard, causing cankers and die back of young shoots, resulting in loss of fruiting wood and increasing pruning costs. Apple canker can be particularly damaging in young orchards where, in some years, up to 10% of trees can be lost annually in the first few years of orchard establishment as a result of trunk cankers, particularly following exceptionally wet or cold winters. *N ditissima* also causes a fruit rot that can result in significant losses as high as 10% or more in stored fruit. *Neonectria* rot, which is often at the fruit stalk end, is also difficult to spot on the grading line, but becomes obvious during marketing, leading to rejection of fruit consignments.

In 2013 the incidence of canker in apple orchards was exceptionally high as a result of wet weather during leaf fall in 2011 and 2012 and above average rainfall in spring and summer 2012. Of particular significance was the high incidence of trees with systemic canker in young orchards, which is most likely to have arisen from infection in the tree nursery. This is especially important given that many growers are investing in new orchards with cultivars that are particularly susceptible and/or sensitive to canker, so the problem will only get worse.

Much is known about the epidemiology of apple canker but there are still significant gaps in knowledge which will require more long term research and are now being addressed in the new AHDB Horticulture project TF 223 on tree fruit IPM, which started in April 2015. However, in the short term control of the cankers and fruit rot is still very dependent on fungicide sprays and, even when new approaches are developed, it is likely that fungicides will still play an important role in the integrated approach.

Currently, canker is controlled by a combination of cultural methods to remove canker lesions and the use of protectant fungicides. Effective fungicides are currently limited. Generally copper fungicides are used at autumn leaf fall and before budburst to protect leaf scars and bud-scale scars. Previously, products based on carbendazim were applied during the spring and summer to prevent tree and fruit infection in this period. These products are

no longer approved for use. In AHDB Horticulture project TF 144 potential alternative fungicides were evaluated for canker control and tebuconazole (Folicur) was identified as a possible alternative product and now has an EAMU (0115/2015) for post-harvest use during leaf fall. However, products effective against *Neonectria* that can be used during the growing season are limited. There is now a range of fungicides from new chemical groups (SDHI group) and alternative products and biocontrol agents that could potentially be active against *N. ditissima* which are worth evaluating.

Objectives

1. To evaluate new fungicides and alternative chemicals applied post-blossom and pre-harvest for control of *Neonectria* fruit rot.

2. To evaluate new fungicides and alternative chemicals applied post-harvest during leaf fall for control of canker.

3. To evaluate the effect of sodium hypochlorite on canker sporulation.

Objective 1 – *Neonectria* fruit rot

Materials and methods

Site location

Plot EE183 – Located at East Malling Research. (E-Longitude 0.45256376, N-Latitude 51.285903). The orchard was planted in 1997 and is 0.25 ha in size and consists of two rows of cv. ‘Royal Gala’ alternating with Self Fertile cv. ‘Queen Cox’ or cv. ‘Red Pippin’, all on M9 rootstock with 1.75m between trees in the row and 3.5m between rows.

The cv. ‘Royal Gala’ trees had a mean height of 225 cm (ground to mean foliage height), mean stem height of 76 cm (ground to first branch) and mean foliage height of 149 cm (tree height – stem height).

Experimental treatments

Twelve treatments, including an untreated control as detailed in Table 1. Fungicide treatments were applied as a four spray programme, two from petal fall (BBCH 69) at 14 day interval and two 28 and 14 days pre-harvest. Other treatments were applied at 14 day intervals from petal fall (BBCH 69 – Meier, 2001) to 14 days pre-harvest. Treatment application dates are given in Table 2. Products were compared to Bellis (pyraclostrobin + boscalid) as standard plus an untreated control.

Treatment application

All treatments were applied using a Stihl SR 450 motorised knapsack sprayer at 300 L/ha.

Experimental design

Each plot consisted of three trees separated from adjacent plots in the row by one tree and by a guard row between rows, with an area of 18.375 m^2. Each treatment was replicated four times in a randomised block design. The orchard has a high incidence of *Neonectria* canker at the eastern end, which declines towards the west end of the orchard. The difference in canker incidence was taken into account in the trial design so that the replicate blocks ran east to west.

Other treatments

All plots were sprayed for powdery mildew based on a programme of Systhane (myclobutanil) and Topas (penconazole) and the mildew-specific products Kindred (meptyldinocap), Nimrod (bupirimate) and Cosine (cyflufenamid). Insecticides were applied to all plots according to pest risk. Nutrient sprays were applied to all plots as needed. Where treatments were applied to all plots a tractor-trailed orchard air blast sprayer was used and treatments applied at the standard farm volume of 200 L/ha.

Assessments

Meteorological records

Records of daily maximum and minimum temperature and rainfall were taken from a weather station located approximately 500 m west of the trial orchard at East Malling Research.

Growth stages at application

The phenological stage using the BBCH scale (Meier, 2001) was recorded at application and assessment times (Table 2).

Phytotoxicity

Trees were checked for symptoms of phytotoxicity after each treatment. Records taken were any chlorosis/necrosis on foliage, growth regulatory effects on shoots, assessed on a scale 0-5. (EPPO Guideline PP 1/135(3)):

0 = No symptoms,
1 = 1-5% leaves very slight,
2 = 6-10% leaves slight,
3 = 11-25% leaves moderate,
4 = 26-50% leaves high,
5 = >50% leaves very high

Table 1. Products evaluated in *Neonectria* fruit rot trial at East Malling Research in 2014

Treatment	Product	Active ingredient	Chemical group	Product rate per ha	Timing
1	Untreated	-	-	-	-
2	Bellis	pyraclostrobin + boscalid	Qol+SDHI	0.8 kg	2 sprays at petal fall + 2 pre-harvest
3	HDC F115	experimental	SDHI + DMI	1.2 L	2 sprays at petal fall + 2 pre-harvest
4	HDC F118	experimental	SDHI	0.25 L	2 sprays at petal fall + 2 pre-harvest
5	HDC F119	experimental	Undisclosed	2.5 L	2 sprays at petal fall + 2 pre-harvest
6	Syllit 400SC	dodine	Guanidine	1.7 L	2 sprays at petal fall + 2 pre-harvest
7	HDC F120	experimental	SDHI + DMI	0.5 L	2 sprays at petal fall + 2 pre-harvest
8	HDC F121	experimental	Qol + phthalimides	1.875 kg	2 sprays at petal fall + 2 pre-harvest
9	Serenade ASO	*Bacillus subtilis*	Biocontrol	10 L	Sprays at 14 day intervals from petal fall to pre-harvest
10	Cropbiolife	Natural flavenoids	natural product	50 ml / 100 L	Sprays at 14 day intervals from petal fall to pre-harvest
11	CuPC33 + Activator 90	experimental	inorganic	2.7 L + 0.1%	Sprays at 14 day intervals from petal fall to pre-harvest
12	42Phi Cu	Ammonium phosphite + copper phosphite	inorganic	2 L	Sprays at 14 day intervals from petal fall to pre-harvest

Table 2. Treatment application dates in 2014

Treatment Number	Product / Timing							
	15 May	**27 May**	**9 June**	**23 June**	**7 July**	**21 July**	**4 August**	**18 August**
1	-	-	-	-	-	-	-	-
2	Bellis	Bellis	-	-	-	Bellis	-	Bellis
3	HDC F115	HDC F115	-	-	-	HDC F115	-	HDC F115
4	HDC F118	HDC F118	-	-	-	HDC F118	-	HDC F118
5	HDC F119	HDC F119	-	-	-	HDC F119	-	HDC F119
6	Syllit	Syllit	-	-	-	Syllit	-	Syllit
7	HDC F120	HDC F120	-	-	-	HDC F120	-	HDC F120
8	HDC F121	HDC F121	-	-	-	HDC F121	-	HDC F121
9	Serenade	Serenade	Serenade	Serenade	Serenade	Serenade	Serenade	Serenade
10	Cropbiolife	Cropbiolife	Cropbiolife	Cropbiolife	Cropbiolife	Cropbiolife	Cropbiolife	Cropbiolife
11	CuPC33 + Activator 90	CuPC33 + Activator 90	CuPC33 + Activator 90	CuPC33 + Activator 90	CuPC33 + Activator 90	CuPC33 + Activator 90	CuPC33 + Activator 90	CuPC33 + Activator 90
12	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu

Disease assessments

Fruit scab and fruit rot

All fruit was harvested into crates from the three trees in each plot on 16 September. Fruit scab and *Neonectria* eye rot were recorded on a sample of 200 fruit per plot. All fruit were then stored in controlled atmosphere (3.5ºC, 1%O_2<1%CO_2) until March 2015. The storage conditions were selected to encourage fruit rot development. At the end of the storage period for each plot the total number of fruit was recorded and the rots identified (17-30 March).

Tree canker

The incidence of cankers on each tree in the plot was scored on 21 April 2015 using a 0-5 scale where 0 = no canker and 5 = most branches with canker.

Statistical analysis

The data were analysed using ANOVA. All percentage figures were transformed to the angular scale before analysis. The canker score for each plot was taken into account in the analysis using a covariance analysis to adjust *Neonectria* rot incidence. Figures in bold are statistically significant from the untreated. Figures in bold and underlined are significantly different from other treatments.

Results

Treatment and rainfall

The date treatments were applied and the rainfall recorded seven days before treatment and 14 days after treatment are shown in Table 3. Treatments were all applied on the same day. Significant rain fell during the petal fall treatment period and pre-harvest when fruit are most susceptible to infection by *Neonectria*. Rain fall in the summer was more sporadic, but sufficient rain fell at key times to ensure adequate fruit infection for evaluation of the treatments.

Phytotoxicity

There were no obvious phytotoxic effects of the treatments observed on leaves or fruit.

Tree canker

The mean canker score is shown in Table 4. There was no significant effect of treatments on canker score. The canker scored was present on the trees at the start of the trial and was not influenced by the treatments applied. New cankers from autumn 2014 infections were not yet visible at the time of the assessment in April 2015. The mean canker score per plot is shown in Table 5. Canker incidence was significantly higher in Blocks 3 and 4 compared to Blocks 1 and 2 ($P<0.001$) but within the blocks there were also variability. As tree cankers are the source of inoculum for the fruit rot, the canker score for each plot was used in the statistical analysis to adjust the fruit rot incidence to account for the variability in canker incidence.

Table 3. Rainfall and rain days recorded before and after the treatment periods in 2014

Treatment timing / spray date	Rainfall (mm) in 7 days before treatment	No. of rain days in 7 days before treatment	Rainfall (mm) in 14 days after treatment	No. of rain days in 14 days after treatment
15 May	9.4	3	43.0	6
27 May	41.0	5	17.8	6
9 June	7.0	3	0	0
23 June	0	0	15.0	6
7 July	3.8	2	32.6	8
21 July	20.6	3	18.4	3
4 August	16.0	2	65.0	9
18 August	5.6	4	41.6	8

Fruit rot

The fruit rots recorded at the end of the storage period in April 2015 are shown in Table 6. Brown rot (*Monilinia fructigena*) and *Neonectria* rot were the main rots recorded. The incidence of *Neonectria* rot was significantly reduced compared to the untreated control by treatments 3 (HDC F115), 5 (HDC F119) and 6 (Syllit 400SC). Treatments 7 (HDC F120), 11 (CuPC33+ Activator 90) and 12 (42Phi Cu) showed possible effects but were not significant. Treatments 3 (HDC F115), 6 (Syllit 400SC) and 7 (HDC F120) also significantly

reduced the incidence of brown rot. The incidence of other rots was too low for any meaningful effects to be identified.

Table 4. Mean canker score (0-5) recorded 21 April 2015

Treatment	Product	Mean canker score
1	Untreated	7.5
2	Bellis	7.2
3	HDC F115	6.7
4	HDC F118	8.3
5	HDC F119	8.8
6	Syllit 400SC	7.6
7	HDC F120	8.4
8	HDC F121	8.1
9	Serenade ASO	7.8
10	Cropbiolife	8.1
11	CuPC33 + Activator 90	8.0
12	42Phi Cu	8.7
F Prob		0.796
SED (33)		1.106
LSD (p=0.05)		2.25

Table 5. Mean canker score (0-5) per plot showing variation in wood canker incidence across the trial orchard

Block	Plot	Treat-ment	Canker score	Block	Plot	Treat-ment	Canker score	Block	Plot	Treat-ment	Canker score	Block	Plot	Treat-ment	Canker score
1	1	4	0.3	2	13	9	1.7	3	25	10	2.3	4	37	7	2.7
	2	2	1.0		14	6	1.0		26	3	1.3		38	1	3.3
	3	3	0.7		15	4	2.3		27	4	2.7		39	2	3.0
	4	12	1.0		16	10	0.7		28	9	1.3		40	6	3.3
	5	5	1.7		17	3	0.7		29	11	1.0		41	11	2.7
	6	8	0.7		18	1	0.7		30	6	1.7		42	10	4.0
	7	10	1.7		19	7	1.7		31	2	3.0		43	5	3.7
	8	1	0.7		20	11	2.3		32	8	2.7		44	12	4.0
	9	9	1.0		21	5	1.3		33	7	3.0		45	8	4.7
	10	7	1.3		22	2	0.3		34	1	3.0		46	4	4.3
	11	6	1.3		23	8	1.0		35	12	2.3		47	3	3.3
	12	11	2.0		24	12	2.3		36	5	3.0		48	9	4.0

Table 6. Mean % losses (angular transformed) due to various rots in cv. 'Gala' apples following treatment with various fungicide and alternative chemicals applied at petal fall to pre-harvest in 2014. Fruit was stored at 3.5ºC in controlled atmosphere conditions for six months. *Neonectria* canker score (Table 5) used as covariate for *Neonectria* rot analysis. Figures in brackets are back transformed means data

Treatment	Mean % rots						
	Brown rot	***Botrytis***	***Penicillium***	***Neonectria***	***Phomopsis***	***Colletotrichum***	**Total rot**
Untreated	11.3 (3.8)	2.6 (0.2)	1.6 (0.07)	18.5 (10.1)	1.7 (0.08)	2.8 (0.2)	22.4 (14.6)
Bellis	8.5 (2.2)	1.0 (0.03)	1.0 (0.03)	20.3 (12.0)	2.0 (0.1)	1.5 (0.07)	21.8 (13.7)
HDC F115	**6.2** (1.2)	0.5 (0.01)	0.8 (0.02)	**11.7** (4.1)	2.2 (0.2)	3.1 (0.3)	**12.1** (4.4)
HDC F118	8.7 (2.3)	0.8 (0.02)	2.3 (0.2)	20.4 (12.2)	2.5 (0.2)	3.7 (0.4)	25.4 (18.4)
HDC F119	12.8 (4.9)	1.5 (0.07)	1.6 (0.1)	**14.3** (6.1)	1.9 (0.1)	4.0 (0.5)	21.7 (13.7)
Syllit 400SC	**7.2** (1.6)	2.1 (0.1)	1.1 (0.04)	**11.8** (4.2)	1.3 (0.05)	3.0 (0.3)	**14.0** (5.9)
HDC F120	**8.1** (2.0)	0.6 (0.01)	3.2 (0.3)	16.6 (8.2)	4.1 (0.5)	3.0 (0.3)	20.1 (11.9)
HDC F121	9.6 (2.8)	1.1 (0.04)	3.1 (0.3)	18.8 (10.3)	1.0 (0.03)	1.8 (0.1)	23.4 (15.8)
Serenade ASO	12.1 (4.4)	2.1 (0.1)	2.4 (0.2)	20.2 (11.9)	1.9 (0.1)	3.7 (0.4)	24.8 (17.6)
Cropbiolife	12.9 (5.0)	1.9 (0.1)	2.0 (0.1)	18.2 (9.8)	1.6 (0.08)	4.2 (0.5)	24.5 (17.3)
CuPC33 + Activator 90	13.6 (5.6)	2.4 (0.2)	2.4 (0.2)	15.2 (6.9)	2.3 (0.2)	2.6 (0.2)	22.2 (14.3)
42Phi Cu	11.6 (4.0)	1.1 (0.04)	2.5 (0.2)	15.0 (6.7)	1.6 (0.08)	3.4 (0.4)	21.9 (13.9)
						0	
F Prob	<0.001	0.488	0.376	<0.001	0.788	0.708	<0.001
SED (33)	1.657	1.043	1.038	2.121	1.403	1.335	3.188
LSD (p=0.05)	3.372	2.122	2.112	4.32	2.854	2.715	6.486

Figures in bold are significantly different from untreated

Apple scab and Neonectria *eye rot*

Mean percentage of fruit with scab or *Neonectria* eye rot at harvest is shown in Table 7. 58% scabby fruit were recorded in untreated plots. The lowest incidence of scab was recorded in treatments 3 (HDC F115), 4 (HDC F118), 5 (HDC F119) and 6 (Syllit 400SC). Treatments 3, 4, 5, 6, 7 (HDC F120), 8 (HDC F121) and 11 (CuPC33 + Activator 90) had significantly less scab than the untreated. Treatment 6 (Syllit) had significantly less scab than all other treatments. The incidence of eye rot was more sporadic and did not always relate to the incidence of subsequent fruit rot in store. None of the treatments had any significant effect on eye rot.

Table 7. Mean % fruit with scab or *Neonectria* eye rot recorded at harvest on a sample of 200 fruit following treatment with various fungicides and alternative chemicals applied from petal fall to harvest in 2014

Treatment	Product	Mean % fruit scab	Mean % eye rot
1	Untreated	46.3 (52.2)	3.9 (0.5)
2	Bellis	41.1 (43.3)	3.5 (0.4)
3	HDC F115	**29.8** (24.8)	2.5 (0.2)
4	HDC F118	**27.0** (20.6)	5.7 (1.0)
5	HDC F119	**28.5** (22.8)	4.7 (0.7)
6	Syllit 400SC	**18.6** (10.2)	1.4 (0.1)
7	HDC F120	**39.2** (39.9)	6.0 (1.1)
8	HDC F121	**37.7** (37.3)	7.0 (1.5)
9	Serenade ASO	42.6 (45.8)	2.7 (0.2)
10	Cropbiolife	47.0 (53.6)	1.0 (0.03)
11	CuPC33 + Activator 90	**37.2** (36.5)	4.5 (0.6)
12	42Phi Cu	39.9 (41.1)	4.5 (0.6)
F Prob		<0.001	0.216
SED (33)		3.450	2.164
LSD (p=0.05)		7.019	4.403

Figures in bold are statistically significant from the untreated. Figures in bold and underlined are significantly different from other treatments.

Objective 2 – Wood canker

Materials and methods

Site location

The trial was located in orchard plot TL161 located at Rocks Farm, East Malling. The orchard was planted in 1998 and is 0.84ha in size and consists of cv. ‘Gala’ on M9 rootstock with 2.0 m between trees in the row and 3.9 m between rows. The trees were pruned to

around 2.0 m in height, increasing to 2.5 m in height with extension growth (ground to mean foliage height), with a mean stem height of 76 cm (ground to first branch) and mean foliage height of 149 cm (tree height – stem height). There was a high incidence of *Neonectria* canker in the orchard.

Experimental treatments

Twelve treatments, including an untreated control, were applied as detailed in Table 8. Fungicide treatments were applied as a four spray programme, applied post-harvest at 10% (23 October 2014), 50% (3 November 2014), 90% (24 November 2014) and 100% (15 December 2014) leaf fall. Products were compared to Folicur (tebuconazole) as the standard and an untreated control.

Treatment application

All treatments were applied using a Stihl SR 450 motorised knapsack sprayer at 500 L/ha

Experimental design

Each plot consisted of three trees separated from adjacent plots in the row by one tree and by a guard row between rows with an area of 23.4 m^2. Each treatment was replicated four times in a randomised block design. The orchard had a high incidence of *Neonectria* canker, distributed fairly evenly across the orchard.

Other treatments

All plots received a standard programme for pests and diseases up to the start of the trial.

Assessments

Meteorological records

Records of daily maximum and minimum temperature and rainfall were taken from a weather station located approximately one mile north of the trial orchard – see Appendix Tables A1 and A2.

Table 8. Products evaluated in *Neonectria* leaf fall trial at EMR in 2014

Product	Active ingredient	Chemical group	Rate / ha
Untreated	-	-	-
Folicur	tebuconazole	DMI	0.6 L
Bellis	pyraclostrobin + boscalid	QoI+SDHI	0.8 kg
HDC F115	experimental	SDHI + DMI	1.2 L
42Phi Cu		inorganic	2 L
HDC F118	experimental	SDHI	0.25 L
HDC F119	experimental	?	2.5 L
Syllit 400SC	dodine	Guanidine	2.5 L
HDC F120	experimental	SDHI + DMI	0.5 L
HDC F121	experimental	QoI + phthalimides	1.875 kg
Serenade ASO	*Bacillus subtilis*	Biocontrol	10 L
Cu 33 + Activator 90		inorganic	2.7 L + 0.1%

Results

Tree canker

The incidence of cankers on each tree in the plot will be recorded in June 2015.

Objective 3 - Sodium hypochlorite and canker sporulation

Materials and methods

Site location

The trial was located in orchard plot TL161 located at Rocks Farm, East Malling. The orchard was planted in 1998 and is 0.84ha in size and consists of cv. 'Gala' on M9 rootstock with 2.0 m between trees in the row and 3.9 m between rows. The trees are pruned to around 2.0 m in height, increasing to 2.5 m in height with extension growth (ground to mean foliage height), with mean stem height of 76 cm (ground to first branch) and mean foliage height of 149 cm (tree height – stem height). There was a high incidence of *Neonectria* canker in the orchard.

Experimental treatments

Four treatments, including an untreated control as detailed in Table 9. Treatments were applied once on 2 April 2015. Products were compared to Folicur (tebuconazole) as standard and an untreated control. Sodium hypochlorite (containing 8% chlorine) was applied at a concentration of 50 ml/L, equivalent to 25 L/ha of sodium hypochlorite product containing 14% chlorine. All treatments were applied to run-off using a hand-held sprayer.

Experimental design

Each plot consisted of a single tree. Three similar sized active cankers were marked on each trial tree. Each treatment was replicated three times in a randomised block design. The orchard had a high incidence of *Neonectria* canker, distributed fairly evenly across the orchard.

Table 9. Treatments evaluated for their ability to suppress canker sporulation

Treatment	Product	Active Ingredient	Rate / litre
1	Untreated	-	-
2	Water	-	-
3	Folicur	tebuconazole	0.6 ml
4	Sodium hypochlorite	Bleach (8% chlorine)	50 ml

Assessments

Canker activity was assessed prior to treatment application. Each canker on the tree was washed with 50ml of distilled water from a hand held sprayer. The washings were collected in a plastic tube via a plastic funnel. Collected washings were spun down in a centrifuge, the supernatant discarded and the remainder re-suspended in 2ml of distilled water. A drop of Thymol was added to each tube to prevent spore germination. The tubes were sealed and stored at 4^{o}C until counted. The spore concentration was counted using a haemocytometer slide.

The effect of the treatment on canker sporulation was assessed by washing the cankers as described above. Cankers were assessed for sporulation after treatment on three occasions - approximately 7 days after treatment, approximately 14-21 days after treatment and approximately 4-6 weeks after treatment.

Results

The trial was scheduled for January and February 2015 during the dormant period. However, weather during February, March and April 2015 was exceptionally dry such that cankers were very dried up and almost no conidia or ascospores were recovered from the pre-treatment canker washings. Treatments were delayed until April 2015 but similarly no spores were recovered from the post-treatment washings, including the untreated control. This study will be repeated in Year 2 starting in November 2015.

Overall discussion

The weather from May to harvest 2014 was very favourable for infection of fruit by *N. ditissima* and significant rot developed in store for effective treatments to be identified. Two experimental products HDC F115 and HDC F119 and one existing registered product Syllit 400SC significantly reduced *Neonectria* fruit rot. Currently Syllit can be used on dessert fruit up to blossom and on culinary fruit up to July. It could be used as part of a programme on culinary fruit, applied at petal fall. Syllit was also the most effective product in reducing fruit scab. In 2015 the best products identified in 2014 will be combined into programmes for evaluation.

The cankers selected for the evaluation of sodium hypochlorite appeared to be active on the branches but failed to generate any conidia or ascospores. The reasons for this are not clear but are most likely related to the very dry conditions in February and March 2015. In addition the very wet weather in October, November and December 2014 probably resulted in most spores being released during this period and the dry cool conditions in subsequent months meant that any regeneration of spores was slow.

Conclusions

- Weather conditions at petal fall and pre-harvest were favourable for infection of fruit by *N. ditissima,* with around 10% fruit rot in untreated plots.
- Two experimental products HDC F115 and HDC F119 and one existing registered product Syllit 400SC significantly reduced *Neonectria* fruit rot by up to 50%.
- Treatments HDC F120, CuPC33 and 42Phi Cu showed slight effects but they were not significant.
- Treatments HDC F115, Syllit 400SC and HDC F120 also significantly reduced the incidence of brown rot.
- The incidence of fruit scab was significantly less on fruit treated with HDC F115, HDC F118, HDC F119, Syllit 400SC, HDC F120, HDC F121 and CuPC33 compared to the untreated control. Syllit 400SC was significantly better than all other treatments.
- The trial evaluating the efficacy of fungicides and biocontrol agents in controlling infection of leaf scars by *N. ditissima* will be assessed in June 2015.

Knowledge and Technology Transfer

The project is at an early stage and no technology transfer has been undertaken.

Reference

Meier, U (2001). Growth stages of mono and dicotyledonous plants. BBCH Monograph, 2nd edition. Federal Biological Research Centre for Agricultural and Forestry

Appendix 1. Weather data

Table A2. Weather data East Malling Research 01.03.14 – 31.10.14

Date	Min Temp ºC	Max Temp ºC	Mean Temp ºC	%rH	Rainfall (mm)
01/01/2014	5.6	11.1	8.6	92.74	18.4
02/01/2014	6.2	10.6	9.0	87.39	1.6
03/01/2014	5.6	11	8.7	85.94	9.4
04/01/2014	3.4	9.8	7.6	91.60	11.4
05/01/2014	-0.7	11.4	5.0	96.35	3.8
06/01/2014	10	13	11.6	84.87	3
07/01/2014	8.7	11.5	10.4	84.20	6.2
08/01/2014	7.1	11.2	9.1	92.35	3.2
09/01/2014	4	11.9	8.6	81.91	0.4
10/01/2014	0.5	10.1	5.6	92.34	0
11/01/2014	-1.8	8.8	5.7	87.63	2.4
12/01/2014	-3.7	8.8	3.0	95.91	3.2
13/01/2014	4.8	9.6	7.1	90.99	1.2
14/01/2014	1.6	6.8	4.4	88.80	3.8
15/01/2014	5.6	10.2	8.9	97.87	9.6
16/01/2014	7.1	10.7	8.9	89.70	4.4
17/01/2014	5.5	8.8	7.3	93.40	11.4
18/01/2014	7.4	9.3	8.2	88.75	0.2
19/01/2014	0.1	9.2	6.2	88.50	0.2
20/01/2014	-1.5	7.8	1.9	98.21	0
21/01/2014	-0.5	6.7	3.0	96.97	0
22/01/2014	4.3	9.3	6.4	95.75	1.6
23/01/2014	2.1	8.2	4.7	88.80	1.8
24/01/2014	1.5	8.1	4.9	89.42	2.6
25/01/2014	5.6	11.5	7.6	90.78	8.4
26/01/2014	3	9.7	5.4	85.90	4.6
27/01/2014	1.9	7.7	4.3	84.48	0
28/01/2014	4.1	8.6	5.5	92.99	14.4
29/01/2014	3.3	6.1	4.4	93.92	13.2
30/01/2014	2.4	6	4.1	99.14	14.2
31/01/2014	0.6	8.1	4.4	96.55	10.8
01/02/2014	5.1	9.2	7.0	85.53	7.2
02/02/2014	4.8	10.1	6.8	82.28	0
03/02/2014	4.3	7.9	5.7	88.46	0
04/02/2014	3.3	9	6.6	82.75	0.4
05/02/2014	5.7	9.6	7.7	83.62	17.4
06/02/2014	5.4	10.6	7.8	88.42	16.2
07/02/2014	3.9	9.9	7.7	85.80	3.8

Date	Min Temp ºC	Max Temp ºC	Mean Temp ºC	%rH	Rainfall (mm)
08/02/2014	5.9	9.7	7.7	83.86	11.4
09/02/2014	4	9	6.7	72.92	0.4
10/02/2014	3.1	8.7	5.2	93.69	10.2
11/02/2014	1.6	7.7	4.8	85.11	8.2
12/02/2014	2.6	8.4	5.8	83.13	9.6
13/02/2014	3.2	7.9	5.1	76.63	0.6
14/02/2014	2	11.4	6.4	89.21	20.6
15/02/2014	4.7	10.6	8.0	79.43	10.8
16/02/2014	1.5	9.8	5.3	83.36	0
17/02/2014	2.1	10.8	7.1	89.79	0
18/02/2014	5.1	10.7	7.8	91.98	3.2
19/02/2014	2.3	10	6.4	94.92	0.4
20/02/2014	6.3	11.7	9.5	92.26	1.8
21/02/2014	2.5	9.6	6.2	81.19	0
22/02/2014	2.9	11.5	7.0	81.36	0
23/02/2014	7.2	12	9.9	80.85	0
24/02/2014	7.2	13.7	10.1	80.01	0
25/02/2014	5	11.5	8.4	85.07	4.8
26/02/2014	2	11.1	6.3	85.29	0
27/02/2014	3.1	11.5	7.0	81.95	3.8
28/02/2014	0.7	8.4	5.0	93.42	7
01/03/2014	0.6	8.2	4.4	87.55	0
02/03/2014	-0.7	9.9	5.4	89.20	7
03/03/2014	3.2	8.7	5.8	92.25	5.2
04/03/2014	1.4	10.4	5.9	84.14	0.4
05/03/2014	-1.2	13.3	6.1	80.16	0
06/03/2014	4.2	13.8	8.6	84.28	0
07/03/2014	5.4	15.2	9.1	87.18	0
08/03/2014	4.9	15.5	10.0	78.00	0
09/03/2014	3.5	18.4	10.1	74.23	0
10/03/2014	1.8	14.5	8.0	84.04	0
11/03/2014	6.2	8.6	7.4	91.22	0
12/03/2014	3.1	12.9	7.4	91.64	0
13/03/2014	4.3	15.5	8.0	84.50	0
14/03/2014	0.8	17.4	8.3	81.48	0
15/03/2014	7.7	17.2	11.5	67.93	0
16/03/2014	7.7	18.9	13.2	62.97	0
17/03/2014	5.4	14.3	10.3	79.47	0
18/03/2014	6.7	13.6	10.0	76.72	0
19/03/2014	6.3	13.4	9.4	80.42	0
20/03/2014	6	15.2	9.9	84.34	0.4
21/03/2014	5.7	11.8	8.4	77.96	4
22/03/2014	4.2	10.6	7.1	75.48	0.8

Date	Min Temp ºC	Max Temp ºC	Mean Temp ºC	%rH	Rainfall (mm)
23/03/2014	1.4	10.3	5.2	81.08	2
24/03/2014	-1.9	10.1	4.6	80.21	0
25/03/2014	4.9	8.9	6.6	84.17	0
26/03/2014	1.2	8.7	3.9	89.93	1.8
27/03/2014	-0.8	9.8	4.3	87.09	0.4
28/03/2014	1.4	13.6	7.7	77.74	0
29/03/2014	3.4	18.5	10.9	72.02	0
30/03/2014	5.4	18.8	11.9	71.28	0
31/03/2014	8	16.4	12.2	77.79	0
01/04/2014	4.3	20.3	12.1	78.43	0
02/04/2014	6.9	19.7	12.6	83.72	0
03/04/2014	8.3	18.8	12.7	84.94	0
04/04/2014	8.8	14.9	12.2	82.73	0
05/04/2014	3.7	16.6	10.1	89.36	0
06/04/2014	12.4	16.1	13.4	93.12	1.8
07/04/2014	9.5	14.2	12.7	95.38	14.2
08/04/2014	5.6	13.4	9.2	70.09	0
09/04/2014	2	17.4	10.0	76.73	0
10/04/2014	2.9	17.4	10.2	77.61	0
11/04/2014	6.1	16.1	11.5	69.64	0
12/04/2014	4.7	15.7	10.4	76.95	0
13/04/2014	7.9	16.6	11.9	68.91	0
14/04/2014	4.9	15.5	10.5	66.48	0
15/04/2014	1	12.9	6.8	76.13	0
16/04/2014	0.1	15.7	8.0	70.86	0
17/04/2014	2.6	20	11.0	70.83	0
18/04/2014	5.6	13.5	9.4	67.00	0
19/04/2014	5.4	13.5	8.8	70.77	0
20/04/2014	6	12.7	9.6	93.47	8.4
21/04/2014	4.7	19.2	11.8	82.55	7.8
22/04/2014	9.4	17	12.1	86.47	20.6
23/04/2014	5.8	18.3	12.4	81.46	0
24/04/2014	9.3	17.1	12.4	85.50	0
25/04/2014	8.3	15.2	10.8	94.90	0
26/04/2014	7.2	15.5	10.9	84.74	3.4
27/04/2014	8.3	16	10.9	86.26	1
28/04/2014	7.4	16.4	12.3	85.33	0
29/04/2014	5.4	16.3	10.9	91.44	0.2
30/04/2014	7.7	20	12.4	81.91	0
01/05/2014	6.2	14.8	10.4	97.39	16.8
02/05/2014	5.9	12	9.7	87.82	0
03/05/2014	1.1	14.2	7.8	71.30	0
04/05/2014	0.3	17.3	9.1	74.20	0

Date	Min Temp ºC	Max Temp ºC	Mean Temp ºC	%rH	Rainfall (mm)
05/05/2014	1.3	18.8	11.4	72.38	0
06/05/2014	9.8	19.6	14.4	72.91	0
07/05/2014	9.1	17	12.9	76.35	0.2
08/05/2014	10.7	14.7	12.4	87.74	3.2
09/05/2014	10.5	18.1	13.9	68.78	0
10/05/2014	10	17.5	12.5	84.31	2.8
11/05/2014	8.9	15.6	11.3	67.00	0
12/05/2014	8.4	16.1	11.7	71.77	0
13/05/2014	6.8	17.3	10.9	84.49	3.4
14/05/2014	5.5	19	12.2	76.04	0
15/05/2014	3.6	21	12.9	75.05	0
16/05/2014	4.3	21.7	14.0	67.53	0
17/05/2014	7.9	23.9	16.2	75.35	0
18/05/2014	8.4	23.8	16.6	71.43	0
19/05/2014	9.1	25.3	18.1	67.26	0
20/05/2014	11.9	21.9	16.6	76.80	0
21/05/2014	9.8	17.9	13.9	86.55	3.6
22/05/2014	11.8	17.8	14.3	85.61	8.8
23/05/2014	9.7	18.5	14.3	71.69	0
24/05/2014	8.5	16.3	11.4	89.63	10.6
25/05/2014	8.4	18.6	13.7	74.98	0
26/05/2014	9.1	17.6	12.7	90.13	9.6
27/05/2014	11.4	12.9	12.2	98.25	8.4
28/05/2014	9.9	14.8	12.2	96.91	2
29/05/2014	11.9	20.2	15.0	86.42	0
30/05/2014	8.7	16.7	13.5	81.90	0
31/05/2014	6.4	19.8	13.6	74.16	0
01/06/2014	10.5	21	15.9	74.76	0
02/06/2014	10.9	21.8	15.2	83.06	0.4
03/06/2014	11.8	20	14.6	84.76	0
04/06/2014	7.1	15.6	12.2	86.68	5.2
05/06/2014	6.1	20.2	13.2	71.66	0.6
06/06/2014	4.9	23.9	15.1	71.33	0
07/06/2014	12.4	24.5	17.7	78.97	1.2
08/06/2014	9.6	25.9	18.2	71.69	0
09/06/2014	12.8	25.7	18.8	80.08	0
10/06/2014	12.4	23.4	18.1	70.20	0
11/06/2014	9.6	23.1	16.2	76.23	0
12/06/2014	9.4	26	18.3	69.12	0
13/06/2014	9.7	25.6	18.2	72.08	0
14/06/2014	13.2	19.5	16.4	82.02	0
15/06/2014	12.1	18	14.8	73.18	0
16/06/2014	12.1	17.4	14.5	78.02	0

Date	Min Temp ºC	Max Temp ºC	Mean Temp ºC	%rH	Rainfall (mm)
17/06/2014	11.8	20.7	15.4	68.95	0
18/06/2014	10.7	21.5	15.5	79.27	0
19/06/2014	7	22.9	14.7	85.99	0
20/06/2014	7	22.7	15.0	74.60	0
21/06/2014	8.4	25.1	17.0	69.42	0
22/06/2014	10.4	24.3	17.7	71.08	0
23/06/2014	9.2	25.8	17.9	69.53	0
24/06/2014	11.9	24.7	17.8	79.63	1.2
25/06/2014	10.2	20.8	15.6	69.52	0
26/06/2014	6.9	20.4	14.5	76.17	0.2
27/06/2014	11	22.9	17.0	75.47	0
28/06/2014	10.1	20.5	15.0	83.06	6.6
29/06/2014	11.3	20	14.4	84.08	3.2
30/06/2014	8.8	20	14.4	80.40	0
01/07/2014	7.8	21.9	15.8	69.83	0
02/07/2014	6.8	24.6	16.2	71.73	0
03/07/2014	10.1	25.5	18.9	64.35	0
04/07/2014	11.5	27.6	19.4	69.47	0
05/07/2014	15.6	22.2	18.0	83.86	2
06/07/2014	13.5	21.3	16.5	81.20	1.8
07/07/2014	8.7	23	16.2	71.96	0
08/07/2014	9.3	20.8	15.3	78.91	0.4
09/07/2014	12.7	22.3	17.1	70.79	0.2
10/07/2014	13.1	17.1	14.7	83.21	9.2
11/07/2014	12.5	16.4	14.4	96.73	2
12/07/2014	14.5	25.5	18.3	85.87	0
13/07/2014	15.2	25.8	19.4	81.62	0.2
14/07/2014	10.4	24.2	17.7	67.90	0
15/07/2014	16.6	26.8	20.4	74.06	0
16/07/2014	11.4	27.7	19.7	74.87	0
17/07/2014	15.1	28.2	21.1	77.55	0
18/07/2014	16.5	32	23.8	70.85	13.2
19/07/2014	17.1	27.9	21.7	83.36	5
20/07/2014	17.4	24.8	20.0	88.61	2.4
21/07/2014	17.1	26.1	20.6	83.14	0
22/07/2014	14.1	26.1	19.8	82.09	0
23/07/2014	14.9	27.2	20.6	80.06	0
24/07/2014	16.1	26.8	21.2	74.69	0
25/07/2014	16.9	26.9	20.8	75.91	0
26/07/2014	17.2	28.9	22.3	70.94	0
27/07/2014	15.7	24	20.3	78.93	0
28/07/2014	15	22.4	17.7	81.73	2.4
29/07/2014	14.6	26.1	19.5	76.80	11.4

Date	Min Temp ºC	Max Temp ºC	Mean Temp ºC	%rH	Rainfall (mm)
30/07/2014	14.3	25.6	19.6	67.92	0
31/07/2014	12.9	25.4	18.9	78.34	0
01/08/2014	12.5	24.2	18.2	79.71	0
02/08/2014	14	24.3	18.2	84.55	4.6
03/08/2014	10.3	23.2	17.4	72.68	0
04/08/2014	10.3	23.2	16.7	75.54	0
05/08/2014	10.8	24.3	17.7	77.33	0
06/08/2014	15.5	25.2	19.3	83.55	9.2
07/08/2014	13.9	26.7	20.1	74.87	0
08/08/2014	13.9	22.4	17.7	94.60	11.6
09/08/2014	12.9	22.9	17.1	80.98	18.8
10/08/2014	13.9	21.3	17.0	86.49	19.2
11/08/2014	11.2	20.5	15.6	77.68	0.6
12/08/2014	10.4	20.7	15.3	75.78	0.2
13/08/2014	9.9	22.1	16.0	77.23	0
14/08/2014	12	21.9	15.3	86.62	2.6
15/08/2014	11.8	20	14.9	88.52	2.2
16/08/2014	10	20.2	15.4	77.74	0
17/08/2014	13.3	19.7	15.7	73.33	0.6
18/08/2014	9.8	19.8	14.5	76.21	0.2
19/08/2014	9.2	17.9	13.4	72.12	0
20/08/2014	6.4	18.6	12.5	74.73	0
21/08/2014	5.3	18.9	12.5	75.55	0
22/08/2014	10.6	20.1	14.8	74.34	0.6
23/08/2014	8.8	19.2	13.5	74.10	0.2
24/08/2014	5.7	19.2	12.7	75.30	0
25/08/2014	10.4	16.5	14.0	96.36	22
26/08/2014	13.6	15.9	15.0	99.54	16.4
27/08/2014	10.3	20.7	15.8	84.41	0
28/08/2014	13.7	22	17.7	87.81	0.6
29/08/2014	11.4	19.7	15.8	87.42	1
30/08/2014	14.9	19.1	16.8	78.68	0.6
31/08/2014	11.6	21.4	15.8	78.89	0
01/09/2014	8.4	19.8	14.7	92.22	0.2
02/09/2014	12.7	20.5	16.0	91.47	0
03/09/2014	11.5	21.9	16.2	89.78	0
04/09/2014	11.6	21.4	16.5	87.75	0
05/09/2014	12.8	20.2	16.2	90.73	0
06/09/2014	11.4	21.2	16.0	90.13	0
07/09/2014	9.7	21.4	15.0	89.95	0
08/09/2014	8.3	21.6	15.0	78.73	0
09/09/2014	8.1	21.1	13.9	84.29	0
10/09/2014	6.6	19.3	12.9	86.15	0

Date	Min Temp ºC	Max Temp ºC	Mean Temp ºC	%rH	Rainfall (mm)
11/09/2014	8.5	18.1	13.9	86.94	0
12/09/2014	12.2	20.7	16.1	85.41	0
13/09/2014	12.6	21.1	16.0	87.41	0
14/09/2014	12.9	20.8	16.2	85.85	0
15/09/2014	11.9	21.7	15.8	88.46	0
16/09/2014	11.6	23	17.3	88.83	0
17/09/2014	15.4	20.5	17.2	91.10	0
18/09/2014	15.4	24.7	18.4	91.07	0
19/09/2014	15	26	19.5	89.52	5.8
20/09/2014	15.3	19.2	17.2	97.00	0
21/09/2014	9.8	18.1	14.6	82.30	0
22/09/2014	6.1	18.5	11.5	84.05	0
23/09/2014	4.8	19.2	11.5	85.21	0
24/09/2014	8.9	18.3	13.4	80.84	1.2
25/09/2014	5.4	19.4	12.6	81.60	0
26/09/2014	12.1	20.1	16.4	86.83	0
27/09/2014	8.1	21.2	14.3	92.48	0
28/09/2014	9.7	24.5	15.6	88.34	0
29/09/2014	10.7	19	14.1	97.85	0.2
30/09/2014	12.4	21.7	16.1	89.58	0.2

Table A2. Monthly rainfall (mm) recorded at EMR in March to September in 2008-2014 compared to 30 year average

Month	2008	2009	2010	2011	2012	2013	2014	30 year average
March	97.8	41.2	43.8	14.6	21.8	59.8	22.0	45.4
April	50.0	34.4	29.4	2.4	113.4	35.6	57.4	46.2
May	67.8	24.2	37.0	12.4	56.8	50.8	69.4	48.9
June	22.2	27.2	49.6	90.8	107.8	14.6	18.6	42.8
July	55.8	60.0	23.0	39.4	102.4	28.6	50.2	40.2
August	60.8	20.8	83.0	50.8	39.2	59.6	111.2	51.6
September	50.8	26.4	52.4	28.2	61.2	42.6	7.6	54.0

Table A3 Original data and statistical analysis

HDC Canker EE183 2014 ORETO 14/013

							% rot						
Plot	**Block**	**Treatment**	**Brown rot**	**Botrytis**	**Phytoph**	**Penicillium**	**Nectria**	**Gloeo**	**Phomopsis**	**Colletot**	**Other**	**Total rot**	**Nectria canker score**
1	1	4	1.3	0	0.2	0.06	2.5	0	1.4	0.3	0	5.7	0.3
2	1	2	1.2	0	0	0	2.5	0	0.3	0.3	0	4.4	1
3	1	3	0.6	0	0	0	0.6	0.06	0.06	0.2	0	1.6	0.7
4	1	12	5.5	0	0	0.3	1.4	0	0.05	0.3	0	7.6	1
5	1	5	2.9	0.2	0	0.06	5.5	0	0	0.6	0	9.3	1.7
6	1	8	2.6	0	0	0.05	2.5	0	0.01	0.4	0	5.8	0.7
7	1	10	4.7	0.2	0	0	2.1	0	0.08	0.7	0.2	8	1.7
8	1	1	2.4	0.1	0	0.2	1.9	0	0.7	0.2	0	5.4	0.7
9	1	9	1.1	0.05	0.05	0.05	1.5	0.05	0.3	0.1	0	3.2	1
10	1	7	0.8	0	0	0.1	2.7	0	0.2	0.05	0	3.9	1.3
11	1	6	0.8	0.3	0	0	0.8	0	0.2	0	0	2	1.3
12	1	11	5	0.4	0	0.1	3.1	0.07	0	0	0	8.9	2
13	2	9	3.2	0.2	0.2	0.1	7.6	0	0.2	0.5	0	11.9	1.7
14	2	6	2.1	0	0	0.1	2	0	0.2	0.3	0	4.8	1
15	2	4	1.2	0.3	0	0	8.4	0	0.1	0.3	0	10.4	2.3
16	2	10	3.2	0.07	0	0.1	2.4	0	0.1	0.4	0	6.2	0.7
17	2	3	0.3	0	0.08	0	0.2	0	0.2	0	0	0.7	0.7
18	2	1	0.9	0.4	0	0	2.7	0.06	0	0.2	0	4.1	0.7
19	2	7	1.3	0	0	0	4.9	0	0.2	0.2	0	6.7	1.7
20	2	11	4.2	0.2	0	0	7.1	0	0.4	0	0	11.9	2.3
21	2	5	3.9	0	0	0.1	2.1	0	0.07	0.3	0	6.5	1.3
22	2	2	2.6	0.07	0	0	4.6	0	0.3	0.07	0.07	7.7	0.3
23	2	8	1.6	0.2	0	0.2	1.6	0.1	0.07	0	0.07	3.8	1
24	2	12	1.8	0	0	0	5.6	0	0.1	0.4	0	7.9	2.3
25	3	10	6	0.4	0	0.3	15.4	0	0	0.3	0	22.4	2.3

Table A3 Original data and statistical analysis

HDC Canker EE183 2014 ORETO 14/013

							% rot						
Plot	**Block**	**Treatment**	**Brown rot**	**Botrytis**	**Phytoph**	**Penicillium**	**Nectria**	**Gloeo**	**Phomopsis**	**Colletot**	**Other**	**Total rot**	**Nectria canker score**
26	3	3	1.6	0.1	0.06	0.1	1.4	0	0.1	0.8	0	4.1	1.3
27	3	4	1.6	0	0	0.06	10.8	0.06	0.06	0.5	0	13.1	2.7
28	3	9	5.4	0.6	0	0.1	9.3	0.07	0	0.5	0	15.9	1.3
29	3	11	4.9	0.1	0.2	1.1	2.3	0.5	1	1.4	0	11.6	1
30	3	6	1	0.2	0.07	0.2	3.1	0	0	1	0	5.6	1.7
31	3	2	1.5	0	0	0.2	15	0	0.1	0.07	0	16.9	3
32	3	8	1.8	0	0	0.6	13.8	0	0.1	0	0	16.4	2.7
33	3	7	1.4	0	0	0.7	13.6	0.1	0.2	0.1	0	16.1	3
34	3	1	3.4	0.06	0.06	0.1	13.3	0	0.1	0.06	0	17.2	3
35	3	12	1.5	0	0	0.07	5.8	0	0.07	0	0	7.4	2.3
36	3	5	7.4	0.1	0	0.1	10.2	0	0.6	1	0	19.5	3
37	4	7	5.9	0.2	0	1.1	17.2	0	2.3	1.2	0	25.8	2.7
38	4	1	11.9	0.4	0	0.1	28.3	0	0	0.7	0	41.5	3.3
39	4	2	4	0.2	0	0.07	27.9	0	0	0	0	32.1	3
40	4	6	2.8	0.2	0	0	10.2	0	0	0.3	0	13.5	3.3
41	4	11	8.5	0.09	0	0.09	17.9	0	0	0.4	0	27	2.7
42	4	10	6.3	0	0	0.3	31.9	0	0.3	0.8	0.1	39.7	4
43	4	5	5.9	0.07	0	0.07	16	0	0.07	0.2	0	22.3	3.7
44	4	12	9.6	0.6	0	0.8	27.8	0	0.1	1.4	0	40.3	4
45	4	8	5.8	0.1	0	0.5	42.6	0	0	0.4	0	49.5	4.7
46	4	4	6.5	0	0	1.3	46.4	0	0	0.6	0	54.8	4.3
47	4	3	2.9	0	0.07	0.07	13.4	0.07	0.3	0.7	0	17.5	3.3
48	4	9	10.1	0	0	0.7	38.8	0	0.1	0.7	0	50.4	4
49	5	1	11.1	0	0	0.5	47.2	0	0	0.4	0	59.2	4

```
"Analysis of HDC Canker EE183 2014 ORETO 14/013"

pointer P;values=!P(Brown_rot,Botrytis,Phytoph,\
Penicillium,Nectria,Gloeo,Phomopsis,Colletot,Other,Total_rot,\
Nectria_canker_score)

print [ch=List;ipr=*;squash=y] P;just=l

calc np=nval(P)

vari [nv=np] SED,Sig,DF


for i=1...np

block
treatment Block+Treatment
covar

if i.eq.5
covar Nectria_canker_score
endif

anova [fprob=y] ang(P[i])
akeep [aov=A] terms=Treatment;mean=M[i];sed=sed
calc IM[i]=iang(M[i])
calc Sig$[i]=A['F pr.']$[2]
calc SED$[i]=max(sed)

calc DF$[i]=A['d.f.']$[3]
if i.eq.5
calc DF$[i]=A['d.f.']$[4]
endif

endfor
```

Appendix 2. Statistical analysis

Analysis of variance

Variate: ANGULAR(Brown_rot)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	333.601	111.200	20.24	<.001
Treatment	11	268.001	24.364	4.43	<.001
Residual	33	181.293	5.494		
Total	47	782.895			

Message: the following units have large residuals.

units 9	-4.22	approx. s.e.	1.94
units 38	4.43	approx. s.e.	1.94

Tables of means

Variate: ANGULAR(Brown_rot)

Grand mean 10.21

Block	1	2	3	4	5
	8.38	8.15	9.64	14.67	

Treatment	1	2	3	4	5	6	7
	11.29	8.54	6.16	8.72	12.76	7.21	8.13

Treatment	8	9	10	11	12
	9.55	12.07	12.89	13.62	11.59

Standard errors of differences of means

Table	**Block**	**Treatment**
rep.	12	4
d.f.	33	33
s.e.d.	0.957	1.657

Analysis of variance

Variate: ANGULAR(Botrytis)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	1.426	0.475	0.22	0.883
Treatment	11	23.312	2.119	0.97	0.488
Residual	33	71.773	2.175		
Total	47	96.511			

Message: the following units have large residuals.

units 44 3.07 approx. s.e. 1.22

Tables of means

Variate: ANGULAR(Botrytis)

Grand mean 1.47

Block	1	2	3	4	5		
	1.25	1.46	1.46	1.73			
Treatment	1	2	3	4	5	6	7
	2.62	1.02	0.45	0.78	1.47	2.07	0.64
Treatment	8	9	10	11	12		
	1.09	2.07	1.93	2.43	1.11		

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.602	1.043

Analysis of variance

Variate: ANGULAR(Phytoph)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	1.2094	0.4031	0.73	0.539
Treatment	11	7.5765	0.6888	1.26	0.292
Residual	33	18.1052	0.5486		
Total	47	26.8912			

Message: the following units have large residuals.

units 1	1.94	approx. s.e.	0.61
units 13	1.60	approx. s.e.	0.61
units 29	1.69	approx. s.e.	0.61

Tables of means

Variate: ANGULAR(Phytoph)

Grand mean 0.34

Block	1	2	3	4	5
	0.32	0.35	0.57	0.13	

Treatment	1	2	3	4	5	6	7
	0.35	0.00	1.14	0.64	0.00	0.38	0.00

Treatment	8	9	10	11	12
	0.00	0.96	0.00	0.64	0.00

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.302	0.524

Analysis of variance

Variate: ANGULAR(Penicillium)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	47.629	15.876	7.37	<.001
Treatment	11	26.599	2.418	1.12	0.376
Residual	33	71.110	2.155		
Total	47	145.338			

Message: the following units have large residuals.

units 29	2.82	approx. s.e.	1.22
units 46	3.06	approx. s.e.	1.22

Tables of means

Variate: ANGULAR(Penicillium)

Grand mean 2.00

Block	1	2	3	4	5
	1.22	0.82	2.81	3.15	

Treatment	1	2	3	4	5	6	7
	1.55	1.02	0.83	2.34	1.64	1.09	3.16

Treatment	8	9	10	11	12
	3.09	2.43	2.02	2.39	2.45

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.599	1.038

Analysis of variance (adjusted for covariate)

Variate: ANGULAR(Nectria)
Covariate: Nectria_canker_score

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
Block	3	162.089	54.030	6.13	0.51	0.002
Treatment	11	428.383	38.944	4.42	0.98	<.001
Covariate	1	384.075	384.075	43.59		<.001
Residual	32	281.985	8.812		2.29	
Total	47	4823.072				

Message: the following units have large residuals.

units 40 -5.46 approx. s.e. 2.42

Covariate regressions

Variate: ANGULAR(Nectria)

Covariate	coefficient	s.e.
Nectria_canker_score	4.97	0.753

Tables of means (adjusted for covariate)

Variate: ANGULAR(Nectria)
Covariate: Nectria_canker_score

Grand mean 16.74

Block	1	2	3	4	5
	13.12	14.68	16.17	22.98	

Treatment	1	2	3	4	5	6	7
	18.48	20.29	11.69	20.41	14.30	11.76	16.61

Treatment	8	9	10	11	12
	18.75	20.21	18.20	15.22	14.96

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	32	32
s.e.d.	1.702	2.121

Analysis of variance

Variate: ANGULAR(Gloeo)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	2.4165	0.8055	1.29	0.293
Treatment	11	7.9319	0.7211	1.16	0.353
Residual	33	20.5671	0.6232		
Total	47	30.9155			

Message: the following units have large residuals.

units 23	1.46	approx. s.e.	0.65
units 29	2.30	approx. s.e.	0.65

Tables of means

Variate: ANGULAR(Gloeo)

Grand mean 0.37

Block	1	2	3	4	5
	0.35	0.27	0.73	0.13	

Treatment	1	2	3	4	5	6	7
	0.35	0.00	0.73	0.35	0.00	0.00	0.45

Treatment	8	9	10	11	12
	0.45	0.70	0.00	1.39	0.00

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.322	0.558

Warning 59, code CA 7, statement 10 in for loop

Command: calc IM[i]=iang(M[i])
Invalid value for argument of function.
The first argument of the IANGULAR function in unit 2 has the value 0.0000

Analysis of variance

Variate: ANGULAR(Phomopsis)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	2.773	0.924	0.23	0.871
Treatment	11	27.386	2.490	0.63	0.788
Residual	33	129.837	3.934		
Total	47	159.996			

Message: the following units have large residuals.

units 1	3.98	approx. s.e.	1.64
units 37	4.95	approx. s.e.	1.64

Tables of means

Variate: ANGULAR(Phomopsis)

Grand mean 2.01

Block	1	2	3	4	5
	2.32	2.12	1.91	1.68	

Treatment	1	2	3	4	5	6	7
	1.65	2.02	2.23	2.50	1.87	1.28	4.10

Treatment	8	9	10	11	12
	0.98	1.88	1.64	2.34	1.61

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.810	1.403

Analysis of variance

Variate: ANGULAR(Colletot)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	25.815	8.605	2.42	0.084
Treatment	11	28.377	2.580	0.72	0.708
Residual	33	117.553	3.562		
Total	47	171.744			

Message: the following units have large residuals.

units 29	3.98	approx. s.e.	1.56
units 35	-3.60	approx. s.e.	1.56

Tables of means

Variate: ANGULAR(Colletot)

Grand mean 3.07

Block	1	2	3	4	5		
	2.54	2.28	3.28	4.17			
Treatment	1	2	3	4	5	6	7
	2.83	1.54	3.12	3.69	3.97	3.00	2.99
Treatment	8	9	10	11	12		
	1.81	3.68	4.17	2.61	3.39		

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.771	1.335

Analysis of variance

Variate: ANGULAR(Other)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	0.4442	0.1481	0.61	0.616
Treatment	11	4.7920	0.4356	1.78	0.098
Residual	33	8.0715	0.2446		
Total	47	13.3077			

Message: the following units have large residuals.

units 7	1.410	approx. s.e.	0.410
units 16	-1.192	approx. s.e.	0.410
units 22	1.039	approx. s.e.	0.410
units 23	1.039	approx. s.e.	0.410
units 25	-0.940	approx. s.e.	0.410

Tables of means

Variate: ANGULAR(Other)

Grand mean 0.154

Block	1	2	3	4	5
	0.214	0.253	0.000	0.151	

Treatment	1	2	3	4	5	6	7
	0.000	0.379	0.000	0.000	0.000	0.000	0.000

Treatment	8	9	10	11	12
	0.379	0.000	1.094	0.000	0.000

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.2019	0.3497

Warning 60, code CA 7, statement 10 in for loop

Command: calc IM[i]=iang(M[i])
Invalid value for argument of function.
The first argument of the IANGULAR function in unit 1 has the value 0.0000

Analysis of variance

Variate: ANGULAR(Total_rot)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	3770.56	1256.85	61.83	<.001
Treatment	11	742.59	67.51	3.32	0.004
Residual	33	670.79	20.33		
Total	47	5183.94			

Tables of means

Variate: ANGULAR(Total_rot)

Grand mean 21.20

Block	1	2	3	4	5
	13.16	14.68	21.38	35.59	

Treatment	1	2	3	4	5	6	7
	22.43	21.75	12.12	25.40	21.73	14.01	20.14

Treatment	8	9	10	11	12
	23.44	24.80	24.54	22.19	21.88

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	1.841	3.188

Analysis of variance

Variate: ANGULAR(Nectria_canker_score)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	3	185.682	61.894	25.31	<.001
Treatment	11	16.760	1.524	0.62	0.796
Residual	33	80.690	2.445		
Total	47	283.132			

Message: the following units have large residuals.

units 1	-3.16 approx. s.e.	1.30
units 29	-2.89 approx. s.e.	1.30

Tables of means

Variate: ANGULAR(Nectria_canker_score)

Grand mean 7.93

Block	1	2	3	4	5		
	5.91	6.39	8.55	10.87			
Treatment	1	2	3	4	5	6	7
	7.51	7.21	6.65	8.32	8.78	7.56	8.37
Treatment	8	9	10	11	12		
	8.13	7.83	8.14	8.01	8.68		

Standard errors of differences of means

Table	Block	Treatment
rep.	12	4
d.f.	33	33
s.e.d.	0.638	1.106

```
1253
1254                                fspread                 (M,IM)[1...np]
1255
1256  fspread List,Sig,SED,DF
```