Project title:	Evaluation of products for control of *Neonectria ditissima* on apples
Project number:	TF 216
Project leader:	Dr Angela Berrie, East Malling Research
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Location of project:	East Malling Research (NIAB-EMR from 9 February 2016), New Road, East Malling, Kent, ME19 6BJ
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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.

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31 August 2016

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GROWER SUMMARY

Headline

- Three fungicides including Syllit 400SC (dodine) and two experimental products, F119 (now registered on apples as Delan Pro) and F115, were effective in reducing Neonectria fruit rot when applied as sprays at petal fall and pre-harvest.

Background and expected deliverables

Canker, caused by the fungus *Neonectria ditissima* (formerly 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, Rubens, 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 project TF 223 (*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.

Control currently relies upon 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 bud burst 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 project TF 144 (*Apple: Evaluation of fungicides for the control of apple canker*), 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

Year 1

In the first year, 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, along with Syllit 400SC (dodine), two alternative chemicals and the biocontrol agent Serenade ASO (*Bacillus subtilis*), were all 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 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 F119 (now available as Delan Pro) and HDC F115, along with 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. Rainfall during the leaf fall period was average to high and should have given conditions conducive to the development and spread of canker. However, actual numbers of cankers associated with leaf scars on extension growth was relatively low and on average about 1 per shoot. One of the lowest numbers was recorded on shoots from untreated plots. There were no significant effects of treatments on numbers of cankers.

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.

Year 2
Neonectria fruit rot

In the second year experimental fungicides and alternative chemicals identified as effective in 2014 were combined in programmes and evaluated for their efficacy in controlling Neonectria fruit rot compared to an untreated control. Programmes evaluated were F115 alone and in combination with 42Phi Cu or CBL, Delan Pro (F119) alone and in combination with 42Phi Cu or CBL and Syllit 400SC in combination with 42Phi Cu and F115. F220, 42Phi and CBL were also applied alone. The fungicides were applied as two sprays at petal fall and two pre-harvest. CBL was applied at monthly intervals and 42Phi Cu applied at 14 day intervals. Fruit was harvested in September and cold-stored in air at 2^{o}C until January when the fruit was removed from store and assessed for rots after two weeks in an unheated barn to allow rot development.

Weather conditions at petal fall and pre-harvest were less favourable for infection of fruit by *N. ditissima* so consequently fruit infection was lower than in 2014 and more variable. None of the programmes or treatments applied significantly reduced Neonectria rot but the lowest incidence was recorded in programmes based on F115 and F119 (Delan Pro) and Syllit 400SC, identified as effective in 2014, and in plots treated with F220. Programmes based on F115, F220 and Syllit 400SC also significantly reduced the incidence of brown rot.

Programmes including 42Phi and Delan Pro significantly reduced Phytophthora rot. The overall incidence of Colletotrichum rot had considerably increased compared to 2014 where incidence was less than 0.5% in most plots. None of the treatments had any significant effect on Colletotrichum rot.

Neonectria canker

In the canker control trial, Bellis, F115, 42Phi Cu, F118, F119 (Delan Pro), Syllit400SC, F220, Serenade + SP057 (wetter) and Captan were evaluated for control of canker. Folicur (tebuconazole) was included as the standard and an untreated control. Products were applied at 10%, 50%, 75% leaf fall as protectants against *N. ditissima* infection of leaf scars. A 4th spray was delayed to coincide with artificial wounds inoculated with *N. ditissima.* The incidence of natural new cankers on extension growth in the autumn leaf fall trial was low and variable with no significant effects of treatments on incidence. However, the highest number of cankers was recorded on untreated plots and the lowest numbers on plots treated with Folicur (standard), Bellis, Syllit, F220, Captan and Serenade + SP057 (wetter). In the inoculated canker trial the treatments Folicur (standard), F115 and Captan all significantly reduced cankers.

In a separate study sodium hypochlorite (14% chlorine) was compared to Folicur (tebuconazole) and a water 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. None of the treatments had any clear significant effect on production of spores by the cankers.

Financial benefits

Apple canker is one of the most challenging disease problems facing the apple industry, mainly because of the difficulties in achieving successful control. Most of the established apple cultivars are very susceptible to the disease and the more recently introduced cultivars such as Jazz, Braeburn, Rubens, Cameo, Kanzi and Zari are also particularly susceptible. 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. Many new orchards are planted as intensive fruit wall systems (c. 3,000 trees/ha) to maximise yield and quality and simplify management and harvesting. Establishment costs are expensive at £7/tree or £21,000/ha. Therefore 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 to control the 'canker problem' available for use in the growing season are limited. This project is not going to solve the 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 Tree fruit project (TF 223).

The information generated from the project will be delivered to the industry through the AHDB Grower journal and joint EMRA / AHDB grower days.

Action points for growers

- This project has identified potential fungicide products that could be used to control Neonectria fruit rot. F119 is now registered for use on apples as Delan Pro. F115 will be registered for use on apples in Europe and may be available in the UK in the future. Syllit 400SC is registered for use on apples and pears but for dessert apples only pre-blossom and for culinary apples up to July. Its future is uncertain but the product owner is hoping to retain it for use in apple.
- Evaluation of new products for canker control should continue as they become available.

SCIENCE SECTION

Introduction

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, Rubens, 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 more long term research and are now being addressed in the new AHDB project TF 223 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 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 use post-harvest during leaf fall. However, products effective against *Neonectria* that can be used in 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.

In the first year, 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 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 (now available as Delan Pro) 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 second year of the project the main objective on control of Neonectria fruit rot was to evaluate programmes combining the most effective products identified in the first year.

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. Rainfall during the leaf fall period was average to high and should have given conditions conducive to the development and spread of canker. However, actual numbers of cankers associated with leaf scars on extension growth was relatively low and on average about 1 per shoot. One of the lowest numbers was recorded on shoots from untreated plots. There were no significant effects of treatments on numbers of cankers. In

the second year of the project the main objective will be to re-evaluate the treatments applied in 2014. In addition, the trial will include inoculation with *N. ditissima* to ensure that infection does occur.

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. This trial will be repeated in December 2015.

Objectives

1. To evaluate programmes combining 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

EE183 – Located at NIAB-EMR. (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 Royal Gala alternating with Self Fertile Queen Cox or Red Pippin, all on M9 rootstock with 1.75m between trees in the row and 3.5m between rows. The Gala trees have 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/programmes were evaluated, including an untreated control. Product details are given in Table 1. The programmes were applied from petal fall / BBCH 70 (Meier, 2001) at 14 day intervals (Table 2). Headland copper was applied at an equivalent dose of copper per hectare to 42Phi Cu to evaluate any additional benefit from the phosphite and bioactivators present in 42Phi Cu.

Treatment application

All treatments were applied using a Stihl SR 450 motorised knapsack sprayer at 300 L/ha following EMR SOP725.

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 run 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 500m west of the trial orchard at NIAB-EMR (See Appendix).

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 were checked for after each treatment and recorded if necessary. Records taken were any chlorosis / necrosis to foliage, growth regulatory effects to 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 NIAB-EMR in 2015

Product	Active ingredient	Chemical group	Product rate per ha
Untreated	-	-	-
HDC F115	experimental	SDHI + DMI	1.2 L
HDC F119 (Delan Pro)*	dithianon + potassium phosphonates	Quinones + inorganic	2.5 L
Syllit 400SC	dodine	Guanidine	1.7 L
HDC F220	experimental	SDHI + inorganic	2.5 kg
Cultigrow CBL	Natural flavenoids	natural product	50 ml / 100 L
42Phi Cu	ammonium phosphite + copper phosphite	inorganic	2 L
Headland Copper	256 g/L copper	inorganic	117.2 ml

* Delan Pro was registered for use on apples during the project

Table 2. Programmes applied and application dates in Neonectria fruit rot trial in 2015

Treatment Number	Product / Timing							
	19 May BBCH 70	**3 June BBCH 70**	**17 June BBCH 71**	**1 July BBCH 72**	**15 July BBCH 72**	**29 July BBCH 75**	**19 August Pre-harvest**	**2 September Pre-harvest**
1	-	-	-	-	-	-	-	-
2	HDC F115	HDC F115					HDC F115	HDC F115
3	HDC F115 + CBL	HDC F115	CBL		CBL	CBL	HDC F115 + CBL	HDC F115 + CBL
4	HDC F115	HDC F115	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	HDC F115	HDC F115
5	Delan Pro	Delan Pro					Delan Pro	Delan Pro
6	Delan Pro + CBL	Delan Pro	CBL	-	CBL	CBL	Delan Pro + CBL	Delan Pro + CBL
7	Delan Pro	Delan Pro	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	Delan Pro	Delan Pro
8	HDC F220	HDC F220					HDC F220	HDC F220
9	Syllit 400	Syllit 400	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	HDC F115	HDC F115
10	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu	42Phi Cu
11	Headland Copper	Headland Copper	Headland Copper	Headland Copper	Headland Copper	Headland Copper	Headland Copper	Headland Copper
12	CBL		CBL		CBL	CBL	CBL	CBL

Disease assessments

Neonectria eye rot

Eye rot was assessed on all three trees per plot on 10 September by recording the number of infected fruit per plot.

Harvest and storage

All fruit was harvested into crates from the three trees in each plot on 23 September. No record was taken of fruit scab as the incidence was very low. All fruit were then stored in air at 2^{o}C from 23 September to December 2015 in Glasshouse Cold store 3. In December 2015 they were transferred to Store 1 in the Crop Handling Centre (CHC), also at 2^{o}C in air. On 15 January the trial fruit was removed from store and left at ambient temperature in the unheated CHC for 2 weeks to allow rot development. At the end of this period for each plot the fruit was weighed and recorded and the rots removed, weighed and identified (10 February-3 March).

Statistical analysis

The data were analysed using ANOVA. All percentage figures were transformed to the angular scale before analysis. Figures in bold are statistically significant from the untreated. Figures in bold and underlined are significantly different from other treatments. In addition the residuals (block and treatment effects removed) for each fungal were plotted for the orchard to show the distribution of rots across the orchard.

Results

Treatment and rainfall

The dates 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. Rainfall during the petal fall period, the critical time for fruit infection by *N. ditissima* was only moderate (34.2 mm) compared to 2014 when rainfall was significant (60.8 mm). Similarly, rainfall through June and July was lower than the same period in 2014, although rainfall pre-harvest was similar. Consequently the risk of fruit infection by *N. ditissima* was expected to be lower for 2015.

Phytotoxicity

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

Table 3. Rainfall and rain days recorded before and after the treatment periods in 2015

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
19 May	18.6	2	14.8	6
3 June	11.8	4	19.4	3
17 June	8.2	2	8.8	4
1 July	0	0	13.8	9
15 July	3.0	5	10.0	6
29 July	7.4	3	8.6	4
19 August	16.6	3	56.0	11
2 September	22.8	6	16.6	5

Fruit rot – Neonectria rot

The incidence of Neonectria rot (Table 4) was much lower than in 2014 as expected due to the weather conditions. Consequently rot incidence was very variable. The highest incidence of rot was in untreated plots and least in plots receiving the combined programmes of treatments 2-9 but none of the differences were significant. The distribution of Neonectria rot in the trial orchard is shown in Figure 1. Note the greater incidence on the eastern side of the orchard corresponding with the higher incidence of canker in the trees.

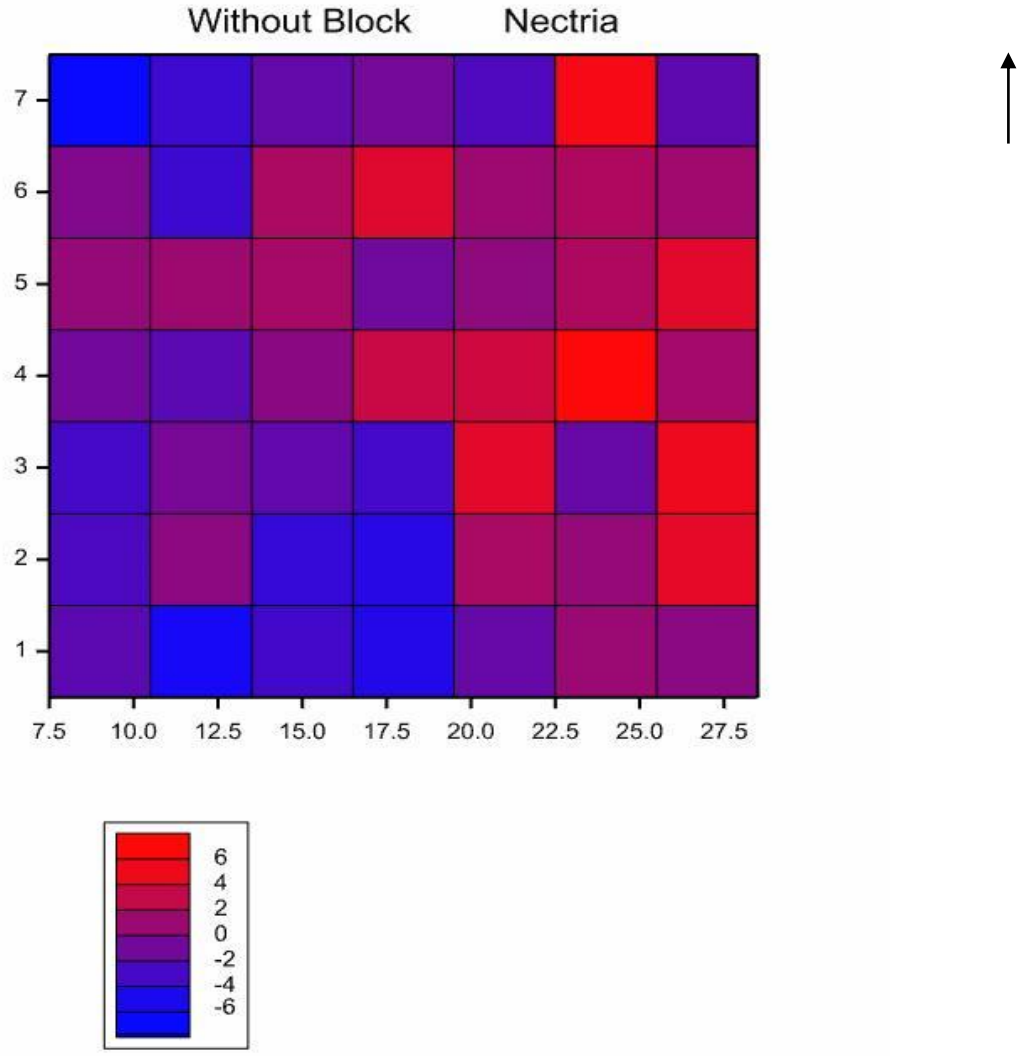

Figure 1. Distribution of % Neonectria rot (angular transformed) in trial orchard. Note greater incidence on eastern side corresponding with greater incidence of canker in trees. Arrow points north

Fruit rot – Other rots

The fruit rots recorded at the end of the storage period are shown in Table 4. Total rots were significantly reduced by programmes 6-8. Brown rot (*Monilinia fructigena*), Colletotrichum rot (*Colletotrichum acutatum*) were the other main rots recorded. Phytophthora rot (*Phytophthora syringae*) was also present consistent with the wetter conditions at harvest in 2015. Treatments HDC F115 and F220 and programmes 3, 4 and 8 all significantly reduced the incidence of brown rot. The incidence of brown rot in the orchard (Figure 3) was fairly evenly distributed across the plots. By contrast, the incidence of Colletotrichum rot in the orchard (Figure 2) was concentrated in the plots in the south east corner where rot incidence was 25-30%, more than three times the incidence in other plots. There is no obvious explanation for this. In addition the overall incidence of Colletotrichum had considerably increased compared to 2014 where incidence was less than 0.5% in most plots. None of the treatments had any significant effect on Colletotrichum rot. Phytophthora rot was present in most plots and fairly evenly distributed across the orchard (Figure 4). Important factors affecting Phytophthora rot, which is soil-borne, are the amount of bare soil under the trees, low-hanging fruit and rain pre-harvest. Programmes including 42Phi and Delan Pro significantly reduced Phytophthora rot. The incidence of other rots was too low for any meaningful effects to be identified.

Table 4. Mean % losses (angular transformed) due to various rots in Gala apples following treatment with various fungicide and alternative chemical programmes applied at petal fall to pre-harvest in 2015. Fruit was stored at 2°C in air for 3.5 months. Figures in brackets are back transformed means data

Treatment	Mean % rots								
	Brown rot	**Botrytis**	***Penicillium***	***Phytophthora***	***Neonectria***	***Colletotrichum***	**Mucor**	**Other rot**	**Total rot**
1 Untreated	14.0 (5.8)	2.0 (0.1)	5.0 (0.8)	5.0 (0.8)	16.1 (7.6)	14.5 (6.3)	-0.04	1.4 (0.06)	29.2 (23.7)
2-F115	**7.9 (1.9)**	2.4 (0.2)	10.3 (3.2)	3.8 (0.4)	13.9 (5.8)	17.5 (9.0)	-0.02	1.8 (0.09)	28.3 (22.4)
3-F115/CBL	**7.3 (1.6)**	2.8 (0.2)	5.3 (0.9)	5.1 (0.8)	10.7 (3.4)	10.9 (3.5)	0.04	0.3 (0)	24.4 (17.0)
4-F115/42PhiCu	**8.1 (2.0)**	4.2 (0.5)	7.5 (1.7)	3.4 (0.3)	11.7 (4.1)	13.9 (5.7)	0.03	1.5 (0.07)	24.2 (16.8)
5-Delan Pro	13.6 (5.5)	3.9 (0.5)	4.3 (0.6)	**0.4 (0)**	11.0 (3.6)	9.1 (2.5)	0.02	2.2 (0.14)	24.3 (16.9)
6-Delan Pro/CBL	10.5 (3.3)	3.4 (0.4)	3.7 (0.4)	2.3 (0.2)	11.6 (4.1)	11.1 (3.7)	0.4	0.2 (0)	**21.1 (13.0)**
7-Delan Pro/42PhiCu	9.5 (2.7)	2.4 (0.2)	2.3 (0.2)	**1.8 (0.1)**	10.1 (3.1)	11.5 (4.0)	0.02	2.5 (0.2)	**19.8 (11.5)**
8-F220	**5.3 (0.8)**	4.0 (0.5)	3.3 (0.3)	2.7 (0.2)	10.3 (3.2)	10.8 (3.5)	0	1.5 (0.07)	**19.6 (11.3)**
9-Syllit/42PhiCu/F115	**7.6 (1.7)**	2.7 (0.2)	7.4 (1.6)	4.2 (0.5)	10.9 (3.6)	12.8 (4.9)	0.06	2.6 (0.2)	24.7 (17.4)
10-42Phi Cu	12.2 (4.5)	4.2 (0.5)	5.4 (0.9)	3.2 (0.3)	13.4 (5.3)	12.7 (4.9)	-0.04	1.2 (0.04)	23.5 (15.9)
11-Headland Cu	14.1 (5.9)	2.8 (0.2)	6.5 (1.3)	4.0 (0.5)	12.6 (4.8)	17.9 (9.4)	0	2.0 (0.12)	30.5)25.7)
12-CBL	11.2 (3.8)	3.0 (0.3)	8.2 (2.0)	3.0 (0.3)	14.5 (6.3)	17.5 (9.0)	-0.02	1.1 (0.04)	28.2 (22.4)
F Prob	0.008	0.884	0.080	0.028	0.345	0.141	0.898	0.147	0.037
Minimum SED (33 df))	1.981	1.404	1.881	1.052	2.051	2.698	0.192	0.773	2.635
Maximum SED (33 df)	2.877	2.039	2.732	1.528	2.978	3.917	0.279	1.122	3.827

Figures in bold are significantly different from untreated

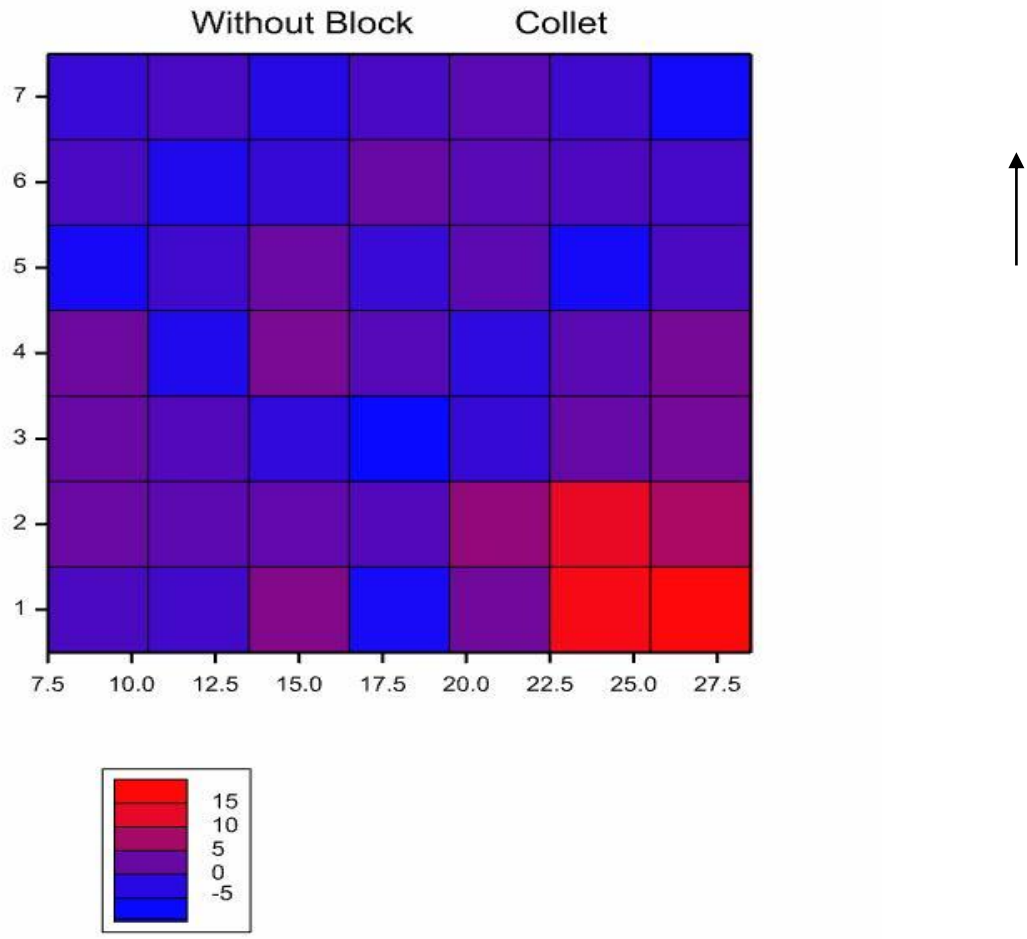

Figure 2. Distribution of % Colletotrichum rot (angular transformed) in plots in trial orchard. Note concentration in south-east corner. Arrow points north

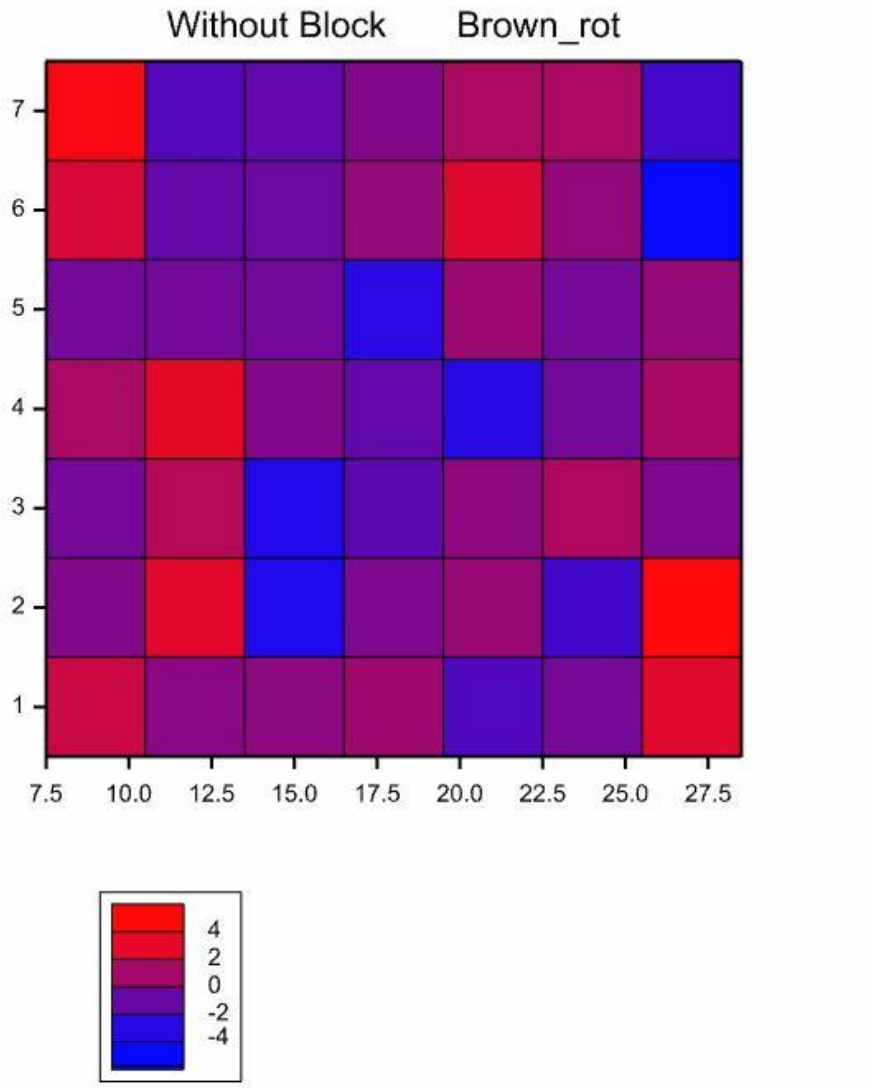

Figure 3 . Distribution of % Brown rot (angular transformed) in plots in trial orchard. Arrow points north

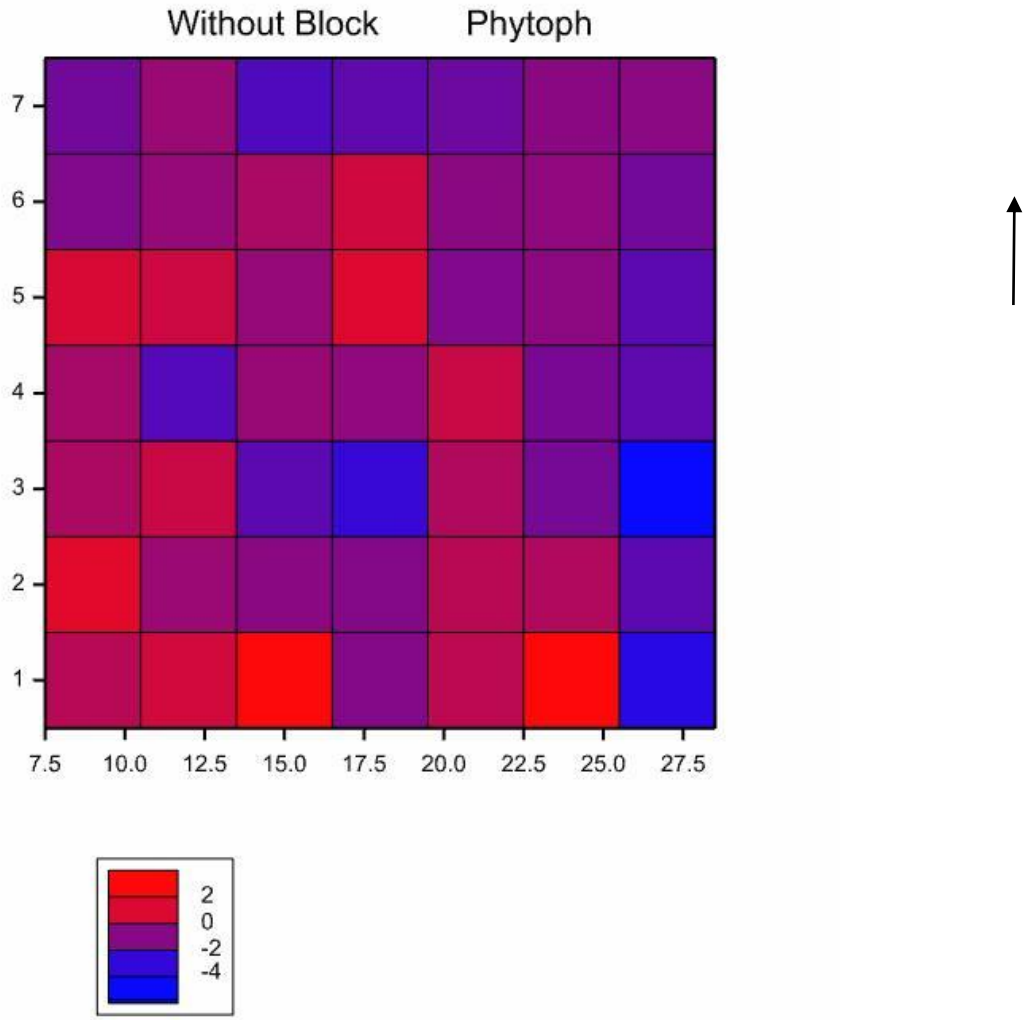

Figure 4 . Distribution of % Phytophthora rot (angular transformed) in plots in trial orchard. Arrow points north

Neonectria eye rot

Mean number of fruit with Neonectria eye rot recorded pre-harvest on the trees is shown in Table 5. The incidence of eye rot was 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 5. Mean number of fruit per plot with Neonectria eye rot recorded pre- harvest following treatment with programmes of various fungicides and alternative chemicals applied from petal fall to harvest in 2015

Treatment	Programme	Mean number of fruit with eye rot
1	1 Untreated	17.2
2	2-F115	8.8
3	3-F115/CBL	17.5
4	4-F115/42PhiCu	15.3
5	5-F119 (Delan Pro)	5.8
6	6-F119 (Delan Pro)/CBL	13.5
7	7-F119 (Delan Pro)/42PhiCu	4.0
8	8-F220	19.8
9	9-Syllit/42PhiCu/F115	3.5
10	10-42Phi Cu	8.0
11	11-Headland Cu	16.3
12	12-CBL	8.5
F Prob		Not significant

Objective 2 – Wood canker

Materials and methods

Site location

The trial was located in orchard MP196 located on NIAB-EMR Main Farm. The orchard was planted in 2012 and is 1.77 ha in size and consists of alternate rows of Gala and Braeburn on M9 rootstock with 1.85 m between trees in the row and 3.5 m between rows. The trees are around 1.5 m in height, increasing to 2.0 m in height with extension growth (ground to mean foliage height), mean stem height of 50 cm (ground to first branch) and mean foliage height of 100 cm (tree height – stem height). There is a high incidence of Neonectria canker in the orchard. The trial was done on cv. Braeburn as a large number of the Gala trees were dead or dying as a result of trunk cankers.

Experimental treatments

Twelve treatments, including two untreated controls as detailed in Table 6. Fungicide treatments were applied as a four spray programme, applied post-harvest at 10% (18 November), 50% (2 December), 75% (10 December) leaf fall. The final spray was delayed until 28 January to coincide with Neonectria inoculation. Products were compared to Folicur (tebuconazole) as standard and an untreated control.

Table 6. Products evaluated in Neonectria leaf fall trial at NIAB-EMR in 2015

Treatment	Product	Active ingredient	Chemical group	Rate / ha
1	Untreated	-	-	-
2	Folicur	tebuconazole	DMI	0.6 L
3	Bellis	pyraclostrobin + boscalid	Qol+SDHI	0.8 kg
4	HDC F115	experimental	SDHI + DMI	1.2 L
5	42Phi Cu		inorganic	2 L
6	HDC F118	experimental	SDHI	0.25 L
7	HDC F119 Delan Pro	dithianon + potassium phosphonates	Quinones + inorganic	2.5 L
8	Syllit 400SC	dodine	Guanidine	2.5 L
9	HDC F220	experimental	SDHI + inorganic	2.5 kg
10	Captan 80WG	captan	Phthalimides	2.0 kg
11	Serenade ASO +SP057	*Bacillus subtilis QST 713* + wetter	Biocontrol	10 L + 0.05 %
12	Untreated	-	-	-

Treatment application

All treatments were applied using a Stihl SR 450 motorised knapsack sprayer at 400 L/ha.

Experimental design

Each plot consisted of 6 trees separated from adjacent plots in the row by one tree and by a guard row between rows with an area of 38.85 m^2. Each treatment was replicated 4 times in a randomised block design. The orchard has a high incidence of Neonectria canker, especially on the western side where the trial was located.

Other treatments

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

Tree inoculation

Eight isolates of *N. ditissima* from the NIAB-EMR culture collection were plated onto water agar and incubated under UV light for 2-3 weeks. Plates were then washed to make up a conidial spore suspension of 1.9 x 10^4 conidia / ml. On 27 January 2016 five trees in each plot were then wounded on three-year-old wood using a file. Each tree was wounded twice giving 10 wounds per plot. Wounds were marked with white paint. On morning of 28 January the fourth spray was applied. Two hours later each wound was inoculated with 0.2 ml of Neonectria spore suspension.

Assessments

Natural tree cankers

Trial trees were left unpruned in winter 2015/16. New tree cankers from natural infection were assessed on 5 July 2016 as total number of new cankers per plot (Table 7).

Inoculated tree cankers

On 14 June the inoculated wounds were assessed using a scoring system where 0 = no canker, 1 = slight infection, 2 = definite canker development. The results were expressed as total score per plot and percentage of wounds infected.

Meteorological records

Records of daily maximum and minimum temperature and rainfall were taken from a weather station located approximately 500 m east of the orchard.

Statistical analysis

The data were analysed using ANOVA. All percentage figures were transformed to the angular scale before analysis. Total number of canker per plot was log transformed (Total cankers + 0.1) before analysis. Total canker score was angular transformed (Total canker score 20.5) before analysis. Figures in bold are statistically significant from the untreated. Figures in bold and underlined are significantly different from other treatments.

Table 7. Mean number of new cankers per plot (log transformed) from natural infection recorded in July 2016 in *Neonectria* leaf fall trial at NIAB-EMR. Figures in brackets are back transformed data.

Treatment	Product	Active ingredient	Mean number of cankers per plot
1	Untreated	-	2.4 (11.4)
2	Folicur	tebuconazole	1.6 (5.0)
3	Bellis	pyraclostrobin + boscalid	1.4 (3.8)
4	HDC F115	experimental	2.8 (16.2)
5	42Phi Cu		2.5 (12.6)
6	HDC F118	experimental	2.3 (9.9)
7	HDC F119 Delan Pro	dithianon + potassium phosphonates	2.1 (8.2)
8	Syllit 400SC	Dodine	1.0 (2.7)
9	HDC F220	experimental	1.2 (3.2)
10	Captan	Captan	1.8 (5.9)
11	Serenade ASO +SP057	*Bacillus subtilis* + wetter	1.4 (4.1)
12	Untreated	-	2.8 (15.7)
F Prob			0.88
SED (33)			1.23
LSD (p=0.05)			2.51

Results

Tree cankers from natural infection

Rainfall during the leaf fall period (Table 8) was average to high and should have given conditions conducive to the development and spread of canker. Actual numbers of new cankers associated with leaf scars on extension growth was relatively low (Table 7) and very variable between replicates and hence no significant differences between treatments were recorded. However, the highest number of cankers was recorded on untreated plots and the lowest numbers on plots treated with Folicur (standard), Bellis, Syllit 400SC, F220, Captan and Serenade.

Table 8. Rainfall and rain days recorded before and after the treatment periods in 2015/2016

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
18 November 10% leaf fall	14	5	22.4	10
2 December 50% leaf fall	4	4	29.4	11
10 December 75% leaf fall	16.8	6	25.4	10
28 January 2016	7.6	3	25.6	8

Tree cankers from artificial inoculation

There was good establishment of cankers from inoculations but with high variability. In untreated plots infection ranged from 20-90 % with a mean of 50 % infection. The treatments Folicur (standard), F115 and Captan all significantly reduced both percentage infection and canker score (Table 9).

Table 9. Mean total canker score (0-2) and mean percent infected inoculated cankers per plot angular transformed recorded in June 2016 in *Neonectria* leaf fall trial at NIAB-EMR. Figures in brackets are back transformed data

Treatment	Product	Active ingredient	Mean Total canker score per plot	Mean % wounds infected
1	Untreated	-	38.4 (38.5)	50.0 (58.7)
2	Folicur	tebuconazole	**10.7 (3.5)**	**14.4 (6.2)**
3	Bellis	pyraclostrobin + boscalid	37.0 (36.1)	39.1 (39.8)
4	HDC F115	experimental	**22.2 (14.2)**	**24.8 (17.5)**
5	42Phi Cu		44.9 (49.9)	51.6 (61.4)
6	HDC F118	experimental	50.1 (58.8)	57.1 (70.5)
7	HDC F119 Delan Pro	dithianon + potassium phosphonates	28.0 (22.0)	36.9 (36.1)
8	Syllit 400SC	dodine	38.7 (39.1)	47.9 (55.0)
9	HDC F220	experimental	43.6 (47.5)	51.6 (61.5)
10	Captan	captan	**14.5 (6.3)**	**17.5 (9.1)**
11	Serenade ASO +SP057	*Bacillus subtilis* + wetter	36.6 (35.5)	48.1 (55.4)
12	Untreated	-	30.2 (25.3)	36.0 (34.6)
F Prob			<0.001	<0.001
SED (33)			8.13	10.04
LSD (p=0.05)			16.54	20.43

Objective 3 - sodium hypochlorite and canker sporulation

Materials and methods

Site location

The trial was located in orchard EE183 at NIAB-EMR. Details as in Objective 1.

Experimental treatments

Four treatments, including an untreated control as detailed in Table 10. Treatments were applied once on 9 December 2015. Products were compared to Folicur (tebuconazole) as standard and a water 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.

Treatment application

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 3 times in a randomised block design. The orchard has a high incidence of Neonectria canker, distributed fairly evenly across the orchard.

Table 10. Treatments evaluated for their ability to suppress canker sporulation

Treatment	Product	Active Ingredient	Rate / litre
1	Water	-	-
2	Folicur	tebuconazole	0.6 ml
3	Sodium hypochlorite	Bleach (8% chlorine)	50 ml
4	HDC F221	experimental	10 ml

Assessments

Canker activity was assessed prior to treatment application. Each canker on the tree was washed with 50 ml of distilled water from a hand held sprayer on 7 December. 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 2 ml 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 3 occasions - approximately 7 days after treatment on 14 December, approximately 14 days after treatment on 21 December and approximately 4 weeks after treatment on 5 January 2016.

Results

Examination of canker washings showed that both conidia and ascospores were present (Table 11) but conidia were the predominant spore type found. Cankers of similar age, size and location were selected for the study, however, despite this cankers varied considerably between and within trees in terms of their ability to produce spores. Prior to treatment conidial spore numbers present on cankers on 7 December were reasonably similar for all treatments. Following treatment application, the pattern of spore production was similar for all treatments. However, cankers treated with Folicur or F221 produced considerably more conidia than the water or sodium hypochlorite-treated cankers at the assessment 7 days after treatment. These two treatments followed a very similar pattern (Figure 5). The lowest final spore count recorded one month after treatment was on Folicur-treated cankers. None of the treatments had any clear significant effect on production of spores by the cankers.

Table 11. Total spore (Conidia or ascospores) production of Neonectria cankers assessed on 7 December (before treatment) and on 14 December, 21 December and 5 January after treatment with water, Folicur, Sodium hypochlorite or F221 on 8 December

Treatment	Product	Date assessed	Mean number spore count	
			conidia	Ascospores
1	Water	7 December	12.1	0.9
		14 December	30.8	0.7
		21 December	5.9	0.5
		5 January	27.1	1.4
2	Folicur	7 December	12.4	0
		14 December	128.5	0.3
		21 December	3.5	0.4
		5 January	9.5	0.3
3	Sodium hypochlorite	7 December	5.0	0.8
		14 December	28.6	4.4
		21 December	16.3	2.1
		5 January	37.9	2.6
4	F221	7 December	27.2	0.2
		14 December	104.8	1.1
		21 December	21.0	4.3
		5 January	74.0	5.4

Table 12. Rainfall and rain days recorded before and after the treatment and spore washing in 2015/2016

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
7 December Pre-treatment	9.0	5	22.2	11
14 December 7 days post-treatment	10.8	6	24.2	8
21 December 14 days post-treatment	17.4	5	54.2	11
5 January 4 weeks post treatment	27.6	6	50.6	9

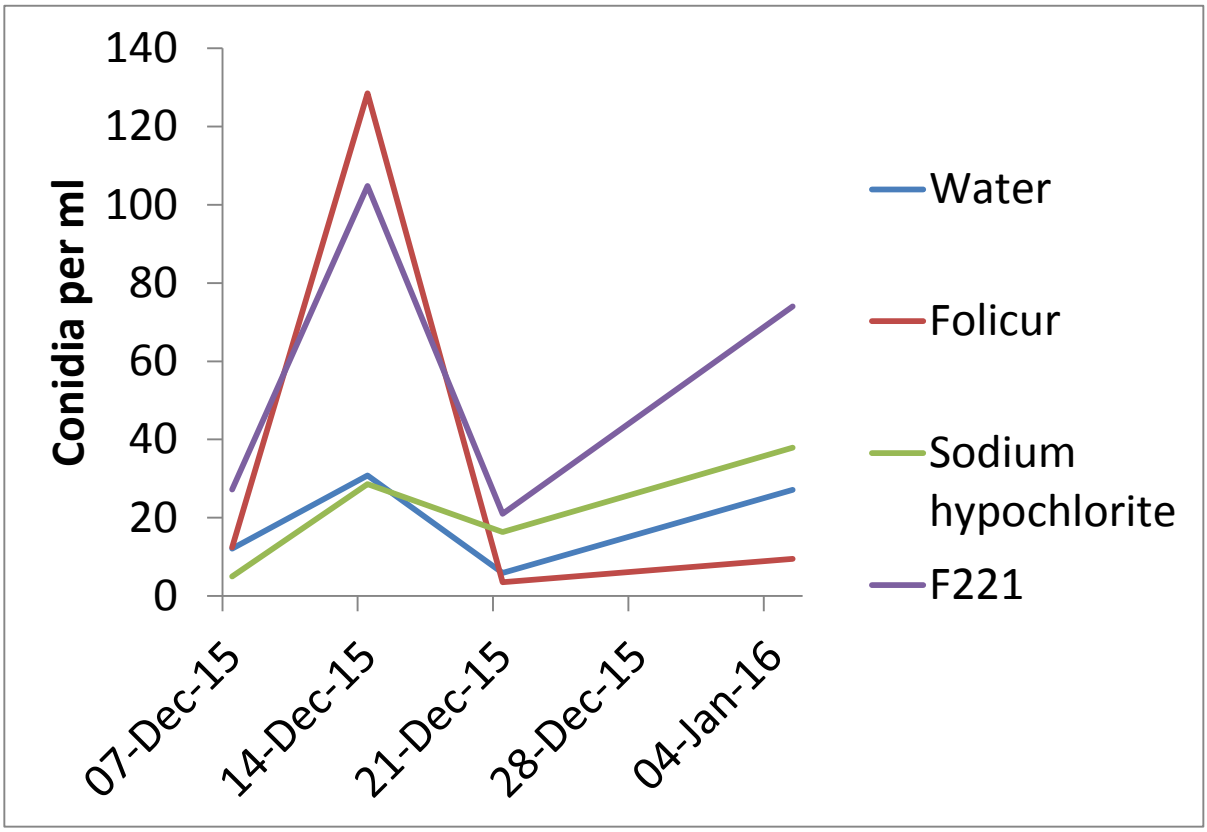

Figure 5. Spore production of Neonectria cankers assessed on 7 December (before treatment) and on 14 December, 21 December and 5 January after treatment with water, Folicur, Sodium hypochlorite or F221 on 8 December

Overall discussion

Previous research has shown that the period from mid-blossom to just after petal fall is the main period for fruit infection by *N. ditissima*. As fruit mature their susceptibility declines but with a slight increase in susceptibility just prior to harvest. The weather from May to harvest was less favourable for infection of fruit by *N. ditissima* compared to 2014. Consequently, incidence of Neonectria rot in store was less and more variable and there were no significant effects of treatments on rot incidence. However, the highest incidence of rot was in untreated plots and least in plots receiving the combined programmes of treatments 2-7 and 9 which were the effective products identified in 2014. In addition treatment 8 (F220) also reduced Neonectria rot. The experimental products HDC F115 and HDC F119 and one existing registered product Syllit 400SC formed the basis of the programmes. Currently Syllit 400SC 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. The product F115 will be registered on apples in Europe and F119 is now registered for use in the UK on apples as Delan Pro.

The programmes applied significantly reduced total rots, brown rot and Phytophthora rot. Programmes which included F115, Syllit 400SC and F220 were effective against brown rot. F115 and Syllit 400SC were also effective in 2014. Phytophthora rot (*Phytophthora syringae*) was also present indicating the wetter conditions at harvest in 2015. Important factors affecting Phytophthora rot, which is soil-borne, are the amount of bare soil under the trees, low-hanging fruit and rain pre-harvest. Programmes including 42Phi and Delan Pro significantly reduced Phytophthora rot. These programmes include copper and potassium phosphite both of which are active against Phytophthora. The overall incidence of Colletotrichum considerably increased compared to 2014 where incidence was less than 0.5% in most plots. In addition, the incidence of Colletotrichum rot in the orchard (Figure 2) was concentrated in the plots in the south east corner where rot incidence was 25-30%, more than three times the incidence in other plots. There is no obvious explanation for this increase in rot incidence or the orchard distribution. Similar effects have been observed in previous experiments also with no obvious reason.

The weather during leaf fall was very favourable for canker spread, infection and development. There was also a high incidence of sporing cankers in the orchard MP196 where the trial was sited. Despite these factors the numbers of cankers that developed on extension shoots was relatively low and very variable between plots and differences were not significant. However, the highest number of cankers was recorded on untreated plots and the lowest numbers on plots treated with Folicur (standard), Bellis, Syllit, F220, Captan and Serenade. Part of the reason for the variable data lies in the pattern of leaf fall in autumn 2015. Leaf fall was slow to start on the variety Braeburn but rapidly accelerated following a frost on 22 and 23 November and windy conditions in mid-November. In addition, individual trees varied considerably in time of leaf fall such that a proportion of the trees in the trial retained many of their leaves well into December, whereas other trees had lost most leaves by mid-November. Consequently, it was impossible to get spray timing correct. Significant results were obtained from the inoculation trial but the results were not entirely in agreement with those from the fruit rot experiments.

The cankers selected for the evaluation of sodium hypochlorite were active on the branches and generated both conidia and ascospores. However, cankers from all treatments showed the same pattern of spore production which was probably more related to weather than to treatment. None of the treatments had any clear significant effect on production of spores by the cankers. The method used to investigate treatment effects has worked well in previous experiments. Perhaps the method used needs revision.

Conclusions

- Weather conditions at petal fall and pre-harvest were less favourable for infection of fruit by *N. ditissima* consequently fruit infection was lower than in 2014 and more variable.
- None of the programmes or treatments applied significantly reduced Neonectria rot but the lowest incidence was recorded in programmes based on HDC F115 and HDC F119 (Delan Pro) Syllit 400SC, identified as effective in 2014, and in plots treated with F220.
- Programmes based on HDC F115, Syllit 400SC and F220 also significantly reduced the incidence of brown rot.
- Programmes including 42Phi and Delan Pro significantly reduced Phytophthora rot.
- The overall incidence of Colletotrichum rot had considerably increased compared to 2014 where incidence was less than 0.5% in most plots. None of the treatments had any significant effect on Colletotrichum rot.
- The incidence of natural new cankers on extension growth in the autumn leaf fall trial was low and variable with no significant effects of treatments on incidence. However, the highest number of cankers was recorded on untreated plots and the lowest numbers on plots treated with Folicur (standard), Bellis, Syllit, F220, Captan and Serenade + SP057.
- In the inoculated canker trial the treatments Folicur (standard), F115 and Captan all significantly reduced both percentage infection and canker score.
- In the canker sporing trial none of the treatments had any clear significant effect on production of spores by the cankers.

Knowledge and Technology Transfer

Results from the first year were presented at the EMRA / AHDB Top Fruit day in November 2015. An article is planned for AHDB Grower.

References

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

Appendix

Table A1. Weather data - East Malling Research 1 March to 31 December 2015

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
01/03/2015	10.6	6.3	3
02/03/2015	11.5	2.3	2
03/03/2015	8.6	1.2	1.2
04/03/2015	9.3	0.8	0.8
05/03/2015	9.9	-1.1	0
06/03/2015	11.9	3.2	0
07/03/2015	11.4	2.6	0
08/03/2015	14.7	3.1	0
09/03/2015	14.3	0.1	0
10/03/2015	9.9	5.3	0
11/03/2015	11	-0.9	0
14/03/2015	12.3	2	0
15/03/2015	6.9	4.1	1.4
16/03/2015	5.7	3.9	2.8
17/03/2015	7.8	4.3	12.6
18/03/2015	10.6	2.4	0
19/03/2015	8.4	3.4	0
20/03/2015	6.7	3.3	0
21/03/2015	7.5	0.8	0
22/03/2015	7.6	2.7	0
23/03/2015	6.3	-2.6	0
24/03/2015	11.2	3.3	1.4
25/03/2015	8.7	-0.4	0.4
26/03/2015	9.5	0.9	4.2
27/03/2015	12.3	4.1	0.6
28/03/2015	12.6	4.6	0
29/03/2015	13.1	8.7	1.6
30/03/2015	13.5	5.9	5.2
31/03/2015	11.8	7.5	1
01/04/2015	13.5	4.6	0.2
02/04/2015	11.4	5.7	2.4
03/04/2015	11.2	6.1	0.4
04/04/2015	11.5	7.2	1.6
05/04/2015	8.6	4.4	0.2
06/04/2015	11.1	-0.8	0
07/04/2015	14.3	0	0
08/04/2015	16.5	4.6	0
09/04/2015	15.6	4.3	0
10/04/2015	15.5	1.6	0

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
11/04/2015	19.7	7.8	0
12/04/2015	13.7	0.7	1.2
13/04/2015	15.7	7.4	0
14/04/2015	15.5	3.2	0
15/04/2015	21.7	5.2	0
16/04/2015	24.2	7.6	0
17/04/2015	14.9	8.3	0
18/04/2015	12.6	5.2	0
19/04/2015	12.6	4.5	0
20/04/2015	11.6	2.8	0
21/04/2015	16.6	4.7	0
22/04/2015	16	5.3	0
23/04/2015	12.9	7.7	0
24/04/2015	15.1	1.7	0
25/04/2015	18.4	10.2	1
26/04/2015	17.3	8.2	3.2
27/04/2015	9.4	1	0
28/04/2015	13	3.1	0
29/04/2015	13.2	4.8	0
30/04/2015	12.2	2.8	7
01/05/2015	14.8	6	0
02/05/2015	11.1	6.5	0
03/05/2015	13.5	9.5	4
04/05/2015	17.2	10.6	0
05/05/2015	17.6	12.1	13.8
06/05/2015	15.2	8.3	2
07/05/2015	13.8	7.8	0.6
08/05/2015	16.1	7.1	0
09/05/2015	17.1	11.1	1.6
10/05/2015	18.2	6	0
11/05/2015	17.5	8.9	0
12/05/2015	20.9	8.6	0
13/05/2015	17.6	3.2	0
14/05/2015	18.3	4.8	0
15/05/2015	10.9	7.7	16.4
16/05/2015	15.2	9.8	0
17/05/2015	18.7	4.6	0
18/05/2015	17.1	7.9	0
19/05/2015	15.6	6.7	2.2
20/05/2015	14.3	5.1	2.6
21/05/2015	15.7	2.5	0.4
22/05/2015	18.8	6.4	0
23/05/2015	19.8	13.4	0

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
24/05/2015	16.3	7.3	0
25/05/2015	19.3	9.5	0
26/05/2015	15.6	8.4	0
27/05/2015	18.8	6.1	0
28/05/2015	19.3	10.3	0
29/05/2015	17.4	8.6	0
30/05/2015	13.4	4.8	7
31/05/2015	16.6	9.9	2.8
01/06/2015	15.1	6.6	0.2
02/06/2015	14.9	10.1	1.8
03/06/2015	16.6	10.3	0
04/06/2015	19.4	5.7	0
05/06/2015	21.6	10.6	11.2
06/06/2015	25.2	7.5	0
07/06/2015	18.9	5.5	0
08/06/2015	19.3	5.4	0
09/06/2015	17.6	7.4	0
10/06/2015	15.1	9.3	0
11/06/2015	18.3	11.6	0
12/06/2015	20.9	12.4	0
13/06/2015	23	14	7.4
14/06/2015	19.9	9.8	0
15/06/2015	16.7	10.8	0.8
16/06/2015	17	5	0
17/06/2015	20.8	9.4	0
18/06/2015	24.5	14.2	0.6
19/06/2015	21	11.9	0
20/06/2015	20.1	10.3	0
21/06/2015	18.4	13.1	3
22/06/2015	20.1	10.3	5
23/06/2015	17.7	11.1	0.2
24/06/2015	19	8.4	0
25/06/2015	21.7	9.5	0
26/06/2015	24.1	9.6	0
27/06/2015	24.8	11.8	0
28/06/2015	23.9	13.8	0
29/06/2015	21.6	11.7	0
30/06/2015	24.4	9	0
02/07/2015	33.5	15.4	0
03/07/2015	23.6	12.2	0.4
04/07/2015	24.1	16.9	5
05/07/2015	25.2	12.1	3.4
06/07/2015	21.3	10.8	2

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
07/07/2015	22	11.4	0
08/07/2015	22.3	13.1	1
09/07/2015	21	9.5	0
11/07/2015	23.8	12.1	0
12/07/2015	24.6	14.3	0.2
13/07/2015	19	16.1	0.6
14/07/2015	19.9	16.1	0.6
15/07/2015	21.3	16.7	0.6
16/07/2015	23.9	13.9	0
17/07/2015	23.8	14.3	0
18/07/2015	22.9	11.8	0
19/07/2015	22.6	13.3	0.8
20/07/2015	23.9	12.4	0
21/07/2015	21.5	12.6	0.4
22/07/2015	23.5	13.3	0
23/07/2015	22.2	9.2	0
24/07/2015	21.3	13	0
26/07/2015	19.8	10.6	0.6
27/07/2015	17	12.9	6.6
28/07/2015	20.4	13.2	0.2
29/07/2015	19.5	9.3	0
30/07/2015	19.2	10.8	1.4
31/07/2015	19.1	5.5	4.6
01/08/2015	20.6	5.9	0
02/08/2015	21.7	9	0
03/08/2015	23.6	12.4	0
04/08/2015	23.2	12.8	0
05/08/2015	20.1	13.2	0
06/08/2015	22.1	11.2	0
07/08/2015	21	8	0
08/08/2015	24.2	10.9	0
09/08/2015	24.9	8.5	0
10/08/2015	25.6	15.3	0
12/08/2015	20.5	14.9	1.2
13/08/2015	20.7	16.8	1.4
14/08/2015	20.1	17.1	13.6
15/08/2015	22.1	13.9	1.6
16/08/2015	20.3	7.8	0
17/08/2015	18.3	8.2	0
18/08/2015	20	13.1	0
19/08/2015	18.1	11.4	0
20/08/2015	20.8	14.1	4
21/08/2015	21.7	17.2	0.4

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
22/08/2015	25.2	12.3	0
23/08/2015	27.9	18	0
24/08/2015	20.4	10.6	9
25/08/2015	17.4	10.7	13.4
26/08/2015	18.1	13.3	6.4
27/08/2015	19.3	12.9	5.2
28/08/2015	17.5	8.4	0.2
29/08/2015	19.7	11.7	0
30/08/2015	20.7	15.4	3
31/08/2015	19.5	14.3	7
01/09/2015	15.1	12.2	3.8
02/09/2015	17.8	6.8	3.6
03/09/2015	17.4	8.3	0
04/09/2015	15.6	8.1	0.2
05/09/2015	14.8	7.1	0
06/09/2015	15.3	4.4	0
07/09/2015	17.9	6.5	0
08/09/2015	16.6	6.8	0
09/09/2015	15.3	12.2	0
10/09/2015	18.3	7.5	0
11/09/2015	19.3	6	0
12/09/2015	20.2	13.8	1
13/09/2015	19.2	7.2	0
14/09/2015	16.1	6.7	4.4
15/09/2015	16.8	8.4	7
16/09/2015	17.3	8.8	4
17/09/2015	15.3	10.1	18.8
18/09/2015	16.9	9.3	4.6
19/09/2015	17.3	9.6	2
20/09/2015	17.6	5.1	0
21/09/2015	18.8	8.3	0
22/09/2015	15.6	6.5	17
25/09/2015	17.3	6.2	0
26/09/2015	16.2	3	0
27/09/2015	16.2	6.3	0
28/09/2015	16.5	5	0
30/09/2015	16.7	8.2	0
01/10/2015	16.4	5.9	0
02/10/2015	16.1	3.6	0
03/10/2015	16.6	4.2	0
04/10/2015	15.8	3.4	0
05/10/2015	16.5	8.4	0.2
06/10/2015	16.6	14.3	6.6

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
07/10/2015	17.8	13.3	4.6
08/10/2015	14.7	5.6	0
09/10/2015	15.4	2	0
10/10/2015	15.2	5.7	0
11/10/2015	15	7	0
12/10/2015	13.6	5.9	0
13/10/2015	12.3	6.8	0
14/10/2015	11.7	6.1	0.4
15/10/2015	13.2	7.4	1.2
16/10/2015	11.4	8.2	1
17/10/2015	11.1	9.7	2.4
18/10/2015	12.1	9.6	0
19/10/2015	13.9	10	0
20/10/2015	13.2	3.1	0
21/10/2015	13.9	3.9	2.2
22/10/2015	13.3	9.3	3.6
23/10/2015	13.6	8.3	0
24/10/2015	12.8	9.9	0
25/10/2015	13.6	2.4	4.8
26/10/2015	12.4	1.3	0
27/10/2015	14.4	7.3	0
28/10/2015	17.1	11.6	18.6
29/10/2015	15.5	0	0.2
30/10/2015	13.8	12	2
31/10/2015	15.4	5.7	0.8
01/11/2015	14.1	3.9	0.2
02/11/2015	12	7.7	0.6
03/11/2015	14.1	7.3	0
04/11/2015	13	7.4	10.4
05/11/2015	14.3	11.3	1.6
06/11/2015	14.9	12.6	8
07/11/2015	16.2	13	4.2
08/11/2015	16.7	6.7	2
09/11/2015	15.8	8.6	0
10/11/2015	14.2	10.4	0
11/11/2015	15.4	12.5	1
12/11/2015	15.1	10.2	0
13/11/2015	14.7	7.5	0.2
14/11/2015	11.8	6.2	0.2
15/11/2015	14.4	8.1	8
16/11/2015	15.2	12.3	0
17/11/2015	14	10.9	3
18/11/2015	15.2	9.6	2.6

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
20/11/2015	12.1	6.7	2.4
21/11/2015	8.2	0.9	2
22/11/2015	5.1	-3.5	1.6
23/11/2015	5.3	-3.2	0
24/11/2015	9.4	0.5	11.2
25/11/2015	9.7	6.3	1
26/11/2015	9.8	2.6	0
27/11/2015	10.9	5.6	0
28/11/2015	11.4	1.9	1
29/11/2015	10.6	3.4	0.2
30/11/2015	12.8	7.7	2.6
01/12/2015	12.8	11	0.2
02/12/2015	13.8	10.2	0
03/12/2015	12.2	10.7	0.2
04/12/2015	12.8	4.7	7
05/12/2015	11.8	5.7	0
06/12/2015	12.1	10.7	0.2
07/12/2015	13.3	10.9	1.4
08/12/2015	12.1	9.7	6.6
09/12/2015	12.9	1.3	1
10/12/2015	11.4	2.9	0.6
12/12/2015	10.7	3.9	0.2
13/12/2015	12.2	6	1
14/12/2015	9.6	6.2	0
15/12/2015	10.3	7.5	3.8
16/12/2015	12.8	10.3	7.4
17/12/2015	14.6	11.3	0.2
18/12/2015	14.6	9.8	1
19/12/2015	13.8	11.1	0
20/12/2015	15.7	11.5	0
21/12/2015	12.9	6.2	5
22/12/2015	13.5	7.8	2.8
24/12/2015	11.8	8.1	0
25/12/2015	12.7	3.3	1.8
26/12/2015	14	8.2	2.2
27/12/2015	13.9	12.4	0
28/12/2015	13.4	7.2	0
29/12/2015	12	9.2	0.4
30/12/2015	11.9	7.5	0.8
31/12/2015	12.2	7.1	5.4
WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
03/01/2016	10.4	4.8	3
04/01/2016	8.2	4.2	11

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
05/01/2016	9	5.9	7
06/01/2016	9.4	1.6	9.4
07/01/2016	8	3.6	10.4
08/01/2016	10.1	-1.9	2.8
09/01/2016	9.6	-0.6	8.4
10/01/2016	9.9	4.6	14.6
12/01/2016	6.9	3.4	0.8
13/01/2016	6.8	2.6	0.8
14/01/2016	6.2	1.2	3.2
15/01/2016	6.3	0	0
16/01/2016	5.2	0.5	0
17/01/2016	4.5	-1.2	0.2
19/01/2016	3.4	-5.9	0
20/01/2016	5.8	-6.3	0
21/01/2016	4.7	-5	0
22/01/2016	7.1	-1.4	0.2
23/01/2016	9.6	1.6	5.2
24/01/2016	11.4	2.9	2.2
25/01/2016	13.1	5.9	0
26/01/2016	13.2	5	0
02/02/2016	12.8	8.8	0
03/02/2016	10.1	1.7	0
04/02/2016	10	3.7	1
05/02/2016	13.7	8.6	0
06/02/2016	11.1	9.3	0.4
07/02/2016	11.5	5.1	4
08/02/2016	10.6	6.6	8.4
09/02/2016	9.8	4.7	1.4
12/02/2016	8.9	-2.5	0.8
13/02/2016	5.5	-1.8	0
14/02/2016	4.5	2.5	8
15/02/2016	6.2	0.3	0
16/02/2016	5.7	-3.9	0
18/02/2016	7.4	3	1.6
19/02/2016	7.5	-3.5	0
20/02/2016	9.8	1.2	0.4
21/02/2016	12.6	8.8	0.6
22/02/2016	13.2	8	2
23/02/2016	8.5	2.8	2.8
24/02/2016	9	-4.1	0
26/02/2016	5.8	-4	0.2
27/02/2016	5.9	-1	0
28/02/2016	5.9	2.9	0

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
29/02/2016	7.4	0.9	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

		HDC Canker EE183 2015 ORETO 15/007										
							% rot					
Plot	Block	Treatment	Brown rot	Botrytis	Penicillium	Phytoph	Nectria	Collet	Mucor	Other	Total rot	Total yield kg
1	1	7	4	0.6	0.6	0.3	1.8	5.2	0	0.2	12.5	151.25
2	1	8	1	0.4	0.8	0.6	2.3	5.5	0	0.2	11.7	132.1
3	1	5	5.1	0.5	0.3	0.04	2	3.4	0	0	13	142.1
4	1	9	2.7	0.3	2	0.7	3.9	5.5	0	0.6	15.7	137.1
5	1	2	1.9	0.3	6.2	1.1	5.3	4	0	0.8	19.7	131.1
6	1	12	6	0.3	3.7	0.4	6.7	8.5	0	0.3	19.8	115.1
7	1	6	7.6	0.2	1.5	0	1.5	1.8	0	0.2	13.4	110.2
8	1	3	1.8	0.4	1.6	1.7	0.6	1.8	0	0	16.6	103.1
9	1	10	7.6	0.8	1.6	0.4	4.1	5.9	0	0	19.9	86.75
10	1	1	6.3	0.6	1.6	1.3	6	4.8	0	0	20.9	109.5
11	1	11	8.9	0	0.7	0.2	3.2	4.7	0	0.8	20.4	126.35
12	1	4	1.5	2.7	3.7	0.9	5	3.7	0	0.4	19	149.4
13	2	11	4.4	3.9	6.1	0.7	2.3	4.7	0	0.04	23.3	120.4
14	2	10	3.2	2.7	5	0.4	1.7	4.6	0	0.13	19.6	117.5
15	2	6	3.8	0.1	1	0.05	5.8	5.4	0	0.05	9.8	97.85
16	2	1	5	0.6	4.4	2.2	3.9	8.5	0	0	24.4	90.3
17	2	5	2.8	0	1.1	0	1.6	3	0	0	11.9	113.45
18	2	7	0.7	0.04	1	0	1.9	3.6	0	0	7	124.95
19	2	3	1.4	0.3	1.6	0.9	4.4	3.7	0	0.04	15.6	125.35
20	2	8	0.7	0.1	0.06	0.2	5.7	2.5	0	0.1	10	87.4
21	2	4	1.2	0	3.3	0.05	2.9	2.4	0	0	11.5	94.45
22	2	2	2.8	0	1	0.3	1.6	4.1	0	0	13.2	91.85
23	2	9	1.8	0	0.7	0.4	1.7	3.8	0	0.2	15	111.5
24	2	12	2.6	0	1.3	0.04	4.1	3.7	0	0	16.1	117
25	3	9	1.3	0.2	0.8	0.5	7.6	3.9	0	0.8	16	121.1

		HDC Canker EE183 2015 ORETO 15/007										
							% rot					
Plot	Block	Treatment	Brown rot	Botrytis	Penicillium	Phytoph	Nectria	Collet	Mucor	Other	Total rot	Total yield kg
26	3	7	0.8	0.9	0	0.6	2.3	4	0	0.34	8.5	131.25
27	3	6	4.3	0.5	0.5	0.3	10	4.3	0	0	20.4	120
28	3	8	1	0.9	0.7	0	3.5	3.5	0	0.1	9.7	138.25
29	3	10	3.1	0.7	1.6	0.7	2.8	7.5	0	0	16.2	114.6
30	3	4	2.2	0.5	0.4	0.7	5.5	9.9	0	0.04	19	133.1
31	3	11	5.7	0.6	1	1	9.1	6.3	0	0	23.9	135.6
32	3	2	0.7	0.1	1.4	0.9	7.9	5.6	0	0.3	16.9	148.9
33	3	1	5.5	0.05	0.09	0.5	7.1	5.5	0	0.05	21.5	108.6
34	3	5	8.8	0.4	0.7	0	4.9	2.6	0	0.7	20.7	135.2
35	3	3	2.5	0	0.8	0.5	1.7	2.8	0	0	15.7	120.1
36	3	12	3.2	0.3	0.7	2	7.9	28.3	0	0	34.1	117.1
37	4	11	3.5	0.03	0.6	1	5.4	25.3	0	0.06	35.8	163
38	4	4	2.7	0.04	0.7	0.2	3	6.2	0	0	14.8	139.6
39	4	3	1.4	0.4	0.3	0.6	8.7	2.9	0	0.09	15.1	117.4
40	4	12	3.2	0.3	0.07	0.5	8.9	4.5	0	0.07	17.9	148
41	4	9	2.2	0	0.7	0.5	6.4	3.5	0	0.2	15.1	161.55
42	4	5	6.9	0.2	0.5	0	9.2	1.5	0	0.2	19.2	125.1
43	4	8	1.6	0.09	0.5	0	5.4	6.4	0	0.09	20.4	112.8
44	4	2	4.5	1	3.9	0	4.9	28.9	0	0	44.4	77.1
45	4	7	5.8	0.1	0.06	0	6.7	13.5	0	0.06	29.4	89
46	4	1	4.5	0	0	0	12.3	7.3	0	0	30.3	103.7
47	4	10	5	1.5	0.1	0.07	7.8	4.8	0	0.1	21.9	153
48	4	6	1.2	0.08	0	0	6.8	2.4	0.08	0	10.7	122.8
49	5	1	3	0.2	0.2	0.6	4.9	1.5	0	0	13.9	138.2

HDC canker Leaf fall trial MP196 ORETO 15/15							
Plot	**Treatment**	**Block**	**Total nat**			**Inoc cankers**	
			cankers/plot		**% infected**		**Total canker score**
1	5	1	18		60		10
2	11	1	21		30		3
3	7	1	8		40		6
4	10	1	2		30		4
5	2	1	1		40		5
6	4	1	17		0		0
7	6	1	19		60		11
8	3	1	43		30		6
9	12	1	16		40		6
10	9	1	3		50		10
11	8	1	32		70		10
12	1	1	143		90		13
13	12	2	29		20		2
14	7	2	14		60		8
15	8	2	2		60		9
16	9	2	11		40		7
17	4	2	38		40		8
18	1	2	64		20		2
19	10	2	49		10		2
20	2	2	28		10		1
21	5	2	2		90		14
22	6	2	6		60		10
23	11	2	13		60		9
24	3	2	9		50		9
25	4	3	21		30		4
26	6	3	12		80		13
27	3	3	0		30		6
28	2	3	19		0		0
29	12	3	26		30		5
30	9	3	3		90		14
31	8	3	0		30		3
32	11	3	11		80		10
33	7	3	8		10		1
34	1	3	0		70		10
35	10	3	6		10		1
36	5	3	84		30		5
37	10	4	2		0		0
38	9	4	1		60		7
39	5	4	8		60		11
40	11	4	0		50		7

HDC canker Leaf fall trial MP196 ORETO 15/15							
Plot	**Treatment**	**Block**	**Total nat**			**Inoc cankers**	
			cankers/plot		**% infected**		**Total canker score**
41	8	4	9		60		10
42	2	4	1		0		0
43	1	4	19		50		7
44	12	4	5		50		8
45	4	4	5		20		3
46	3	4	6		50		8
47	6	4	7		80		13
48	7	4	5		40		4

Project 33109		**canker washing spore counts (mean)**				**2015**							
Treatment	**Plot**	**07/12/2015**						**21/12/2015**			**05/01/2016**		
WHITE	canker	conidia	ascospore		conidia	ascospore		conidia	ascospore		conidia	ascospore	
Water	1 top	4	0		8	0		4.5	0		28.5	0	
	middle	6	0		too muddy to count			1	0.5		13	0	
	bottom	7.5	0		0	0		2	2		0	0	
	6 top	6.5	4.5		8.5	4		1.5	0		33.5	12.5	
	mddle	8.5	1		1.5	2.5		2	2.5		5.5	2.5	
	bottom	37.5	0		129	1		6	0		23	1	
	11 top	8.5	0		62.5	0		5	0		11.5	1	
	middle	8	0		40.5	0		13	0.5		41.5	0	
	bottom	11	0		20	0		14.5	0		89.5	0	
	14 top	3.5	0		25.5	0.5		1	0		47.5	0	
	mddle	36.5	0		32	0		6.5	0		0	0	
	bottom	7.5	5.5		42	0		14	0		31	0	
RED	3 top	1.5	0		8	0		3.5	0		0.5	3	
Folicur	middle	23	0		303.5	0		8	0		22	0	
	bottom	6	0		no liquid in tube			0.5	0.5		2.5	0	
	5	1.5	0		166	1.5		1	1		7.5	0	

Project 33109		canker washing spore counts (mean)				2015							
Treatment	**Plot**	**07/12/2015**						**21/12/2015**			**05/01/2016**		
	top												
	mddle	47	0		38.5	0		8	0		14.5	0.5	
	bottom	22.5	0		61	1		4.5	1		12	0	
	12 top	3.5	0		4	0		0.5	0		2.5	0.5	
	middle	6.5	0		14	0		2.5	0		1.5	0	
	bottom	4	0		13.5	0		2.5	1		3.5	0	
	13 top	12.5	0		363	0		2.5	0.5		0.5	0	
	mddle	1	0		14	0.5		0	0.5		7.5	0	
	bottom	19	0		401	0		9	0		39	0	
BLUE	2 top	2.5	0		9.5	0		1	0.5		15	0	
Sodium hypochlorite	middle	1.5	10		5	34.5		2.5	4.5		11.5	10	
	bottom	1.5	0		14	15.5		1.5	1		9.5	2.5	
	8 top	3.5	0		36	0.5		9	0		43.5	0	
	mddle	2	0		6	0.5		1	0.5		12.5	8	
	bottom	9	0		1	2		10	15.5		10.5	1	
	10 top	1	0		1	0		166	0		9.5	0	
	middle	0.5	0		3.5	0		4	0		7.5	0	

Project 33109		canker washing spore counts (mean)				2015							
Treatment	**Plot**	**07/12/2015**						**21/12/2015**			**05/01/2016**		
	bottom	32	0		218.5	0		4	0		260.5	0	
	16 top	0	0		21	0		25	0		22.5	0	
	mddle	1	0		4	0		4	0		23.5	0	
	bottom	6	0		24	0		11	3.5		28.5	9.5	
YELLOW	4 top	18	0		42	0		18.5	0		81.5	0	
F221	middle	11	0		12	1		3.5	0		56.5	0	
	bottom	4	0		112.5	0.5		15.5	0		38.5	0	
	7 top	110.5	0		384.5	0.5		59.5	0		146.5	0	
	mddle	56	0		77	0		10	0		154	0	
	bottom	24	0		103.5	0		6	0		61	0	
	9 top	25.5	0		38	0		17	1.5		44	0	
	middle	5.5	0		2.5	11.5		6.5	48		164.5	0	
	bottom	0.1	2		140.5	0		17.5	1		3	64.5	
	15 top	28	0		78	0		52.5	0		18	0	
	mddle	40.5	0		263	0		12.5	0.5		110.5	0	
	bottom	3.5	0		4	0		33	0		10	0	