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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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29 September 2009

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CONTENTS

Grower Summary

Headline

Best practice programme reduces tree cankers and fruit rot compared to standard farm practice.

Background and expected deliverables

Canker, caused by the fungus *Nectria galligena*, is one of the most important diseases of apple and pear. 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. In some years, up to 10% of trees can be lost during orchard establishment, as a result of trunk cankers. Nectria also causes a fruit rot that can result in losses as high as 10% or more in stored fruit. Nectria 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.

The fungus produces two spore types, conidia in the spring and summer and ascospores in the autumn and winter. These enter shoots and branches on the tree through either natural wounds, such as bud-scale, leaf and fruit scars or artificial wounds, such as pruning wounds. Inoculum and points of entry on the tree are therefore available all year round and the only limiting factor is frequency and duration of rain, which is essential for spore production, spread, germination and infection. Autumn leaf fall is usually the main infection period and wet autumns are usually followed by a high incidence of shoot die-back due to canker the following spring and summer.

Currently canker is controlled by a combination of cultural methods to remove canker lesions and the use of protectant fungicides. Effective fungicides are limited. Generally, copper fungicides are used at autumn leaf fall and before budburst to protect leaf scars and bud-scale scars. In addition, carbendazim is applied during the spring and summer. In HDC project TF 144, potential alternative fungicides were evaluated for canker control. None of the products evaluated were more effective than carbendazim, but Octave (prochloraz), Folicur (tebuconazole) and Elvaron Multi (tolylfluanid) were as effective or almost as effective as carbendazim and therefore could be considered as potential replacements. There are also other chemicals,

mainly commodity chemicals or nutrients such as potassium phosphite or potassium bicarbonate which may also contribute to canker control.

Tree growth and nutrition may also influence canker infection and development. Canker incidence is often greater in poorly growing trees or in trees with excessive growth. It is most likely that a tree that is subject to stress or that is not in growth balance is more prone to canker. Nitrogen is known to encourage canker development but other nutrients possibly trace elements, may also influence disease development. The factors which are important are not fully understood.

Up until the 1970s it was normal orchard practice to remove prunings from the orchard and burn them. Any cankers pruned out would therefore have been eliminated from the orchard. Removal and burning of prunings from orchards is now rare, most being pulverised in the tree alleyways. What is not clear is the effect of this practice on canker survival and viability and the likely risk to trees from spores generated by canker debris on the ground. Previous studies by Upstone (late 1970s) and Swinburne (early 1980s), which have focused on canker infection in the trees, have indicated a minimal risk. Despite this there are still concerns among growers. Studies on canker pulverisation in HDC project TF161 showed that pruned out cankers pulverised or unpulverised could produce perithecia for at least 16 months after being removed from the trees and so could provide inoculum for infection of wounds.

Applying an integrated programme for canker control is costly, especially pruning out cankers and additional fungicide sprays. In addition the intensive fungicide programme can contribute to residues in fruit. Such costs and risks would be considered worthwhile if they resulted in significantly better canker control. However, such an evaluation of the full integrated approach has never been undertaken.

The overall aim of this project was to evaluate a programme in which all the known key methods for canker control were combined, for efficacy in controlling canker. Key methods to be included are:

- Best fungicide programme
- Spray timing
- Summer pruning to remove cankers

- Balanced nutrition

The information generated will be used to produce an HDC Factsheet on canker control.

Summary of project and main conclusions

At two orchard sites, both planted with Gala on M.9 rootstock, the effect of a full integrated programme for canker control on the incidence of new cankers, nectria fruit rot and shoot growth was compared with that of a standard fungicide programme with no additional specific measures for control of canker. At each site the orchard was divided in half. A standard fungicide programme was applied to one half and a best practice programme, with additional treatments for canker control applied at key timings pre- and post-blossom and at leaf fall, to the other half (Table 1). In addition the plots were sub divided to include removal or non removal of cankers during the summer. The soil was sampled at the start of the trial and leaf samples taken for analysis during the season and additional nutrients applied as necessary. The trials were established in October 2005.

The weather in summer 2006 was relatively dry and not very favourable for spread and infection of nectria. Rainfall was higher in 2007 and 2008 and more conducive to canker spread and infection.

At site 1, the programme of treatments applied to the best practice half of the orchard significantly reduced the numbers of new cankers compared to those on trees receiving the standard programme in each of the three years of the trial. The incidence of nectria fruit rot was also reduced compared to that in the half receiving a standard programme. Reduction in rotting was significant in 2006 and 2007 but not in 2008. There was no effect of summer canker removal on nectria rot incidence but this was probably done after the main period for infection of fruit by *N. galligena*. There was no effect of treatments on annual shoot growth in 2006 or 2007. However, in 2008 shoot growth in the parts of the orchard receiving the standard fungicide programme was significantly greater than in the parts of the orchard receiving the best practice programme. Reasons for this are not clear.

At site 2, since the start of the trial, the overall incidence of canker in the orchard has fallen irrespective of treatment. Numbers of new cankers were also reduced by the best practice treatments in each of the years but not significantly so. The incidence of

nectria fruit rot was too low in 2006 and 2007 for any effects to be determined. The incidence of rots was higher in 2008. The lowest incidence of nectria rot was recorded in trees receiving the best practice programme. There was no effect of summer canker removal on fruit rot incidence. There was no significant effect on shoot growth in any of the three years of the trial.

The results of the three year study clearly show that application of an intensive integrated programme for canker control resulted in a significant reduction in numbers of new cankers and nectria fruit rot. However, such an intensive programme is costly and will result in detectable residues in the fruit at harvest. A more targeted fungicide programme may control canker with the minimum risk of residues in the fruit. Further research is needed to determine whether the more targeted fungicide programme would be as effective.

Table 1. Treatments applied to orchard plots at TL161 EMR (Site 1) and Marsh Gala, Elverton Farm, Teynham (Site 2). Each plot was further split for removal or no removal of cankers in summer

Standard Farm Practice	Canker Best Practice
Standard fungicide programme	Standard fungicide programme + additional sprays for canker at key times as follows: 2-3 at bud burst –bloom (protection of bud scale scars and late frost damage) petal fall petal fall + 2-4 weeks (summer leaf fall) June/July (fruit thinning) August (summer pruning) Sprays for fruit rot at bloom and pre-harvest
Cuprokylt at 10% and 50% leaf fall	Folicur pre leaf fall (October), Cuprokylt at 10% and 90% leaf fall, Folicur at 50% leaf fall

Financial benefits of the project

Apple canker is one of the most difficult disease problems facing the apple industry mainly because of the difficulties in achieving successful control of the problem and the expense involved in applying what is considered to be the best practice for control. This project has demonstrated that the effort of applying an intensive fungicide programme is rewarded with a significant reduction in the incidence of both canker and nectria fruit rot. However, such an intensive programme is costly and will result in detectable residues in the fruit at harvest. A more targeted fungicide

programme may control canker with reduced costs and with the minimum risk of residues in the fruit. Further research is needed to determine whether the more targeted fungicide programme would be as effective.

Action points for growers

- This trial has demonstrated that the effort of applying an intensive fungicide programme is rewarded with a significant reduction in the incidence of both canker and nectria fruit rot.

- The key factors in a canker control strategy are summarised below.

Sizing up the problem

- Inspection of orchards for nectria cankers during winter pruning and for shoot die-back in spring/summer will give an indication of the size of the problem in orchards.

- In addition assessment of nectria rot incidence during fruit grading from store will also give an indication of canker incidence in the orchard.

- Problem orchards will need routine treatments every year.

Canker control

- An integrated approach to canker control is essential.

- In winter, prune out cankers where possible or pare back cankers on scaffold branches to healthy tissue. Treat with a suitable canker paint (e.g. Bezel) immediately after pruning.

- Where possible remove prunings from the orchard and burn; otherwise macerate in *situ.*

- Paint wounds on young trees especially those on the trunk or scaffold branches.

- In orchards where canker incidence is low, at leaf fall in autumn, apply a spray of a copper fungicide at 10% leaf fall and repeat at 50% leaf fall.

- In orchards where canker incidence is moderate to high, apply a programme of sprays starting with tebuconazole (Folicur) before the end of leaf fall followed by a spray of a copper fungicide at 10% leaf fall, then a spray of tebuconazole (Folicur) or thiophanate-methyl (Cercobin) at 50% leaf fall with a second copper spray at 90% leaf fall.

- Apply a pre-bud burst copper spray in the spring.

- At bud burst spray dodine (e.g. Radspor) or dithianon (Dithianon) to protect bud scale scars against infection. Repeat at mouse ear.

- Thereafter use dithianon or captan as part of the scab control programme. These products will give some protection against canker. Dithianon + pyraclostrobin (Maccani) or pyraclostrobin + boscalid (Bellis) or cyprodonil + fludioxonil (Switch) will also give some control.

Reducing nectria fruit rot in store

- Identify orchards at risk from nectria rot in spring based on the incidence of cankered trees in the orchard (<5% = low risk, 5-25% = moderate risk, >25% = high risk) and the rot history from pack house records. The risk of nectria rot in store can then be further assessed based on the rainfall between blossom and harvest.

- Apply sprays of captan or pyraclostrobin + boscalid (Bellis) or cyprodonil + fludioxonil (Switch) to orchards where a moderate to high risk has been identified, during blossom and at petal fall. These will give the fruit some protection against nectria rot. In orchards with a high canker incidence (>25% trees with canker), this is essential if fruit is to be stored without significant losses beyond Christmas.

- The same treatments can be applied pre-harvest in late July and August. Thiophanate-methyl (Cercobin, Sola 1813/2008) can also be used pre-harvest, but the current SOLA excludes its use during blossom.

- In orchards where the canker risk is high the best option may be to avoid chemical treatment and schedule the fruit for early marketing before Christmas to minimise losses.

- The nectria risk of fruit from lower risk orchards is based on the amount of rainfall between blossom and harvest. In seasons when rainfall is above average this fruit may also need to be scheduled for early marketing if sprays have not been applied in blossom

Science Section

Introduction

Canker, caused by the fungus *Nectria galligena*, is one of the most important diseases of apple and pear. 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. Nectria also causes a fruit rot that can result in significant losses as high as 10% or more in stored fruit. Nectria 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.

The fungus produces two spore types, conidia in the spring and summer and ascospores in the autumn and winter. These enter shoots and branches on the tree through wounds, either natural such as bud-scale scars, leaf scars, fruit scars or artificial such as pruning wounds. Thus inoculum and points of entry on the tree are available all year round and the only limiting factor is frequency and duration of rain, which is essential for spore production, spread, germination and infection. Autumn leaf fall is usually the main infection period and wet autumns are usually followed by a high incidence of shoot die-back due to canker the following spring and summer.

Currently canker is controlled by a combination of cultural methods to remove canker lesions and the use of protectant fungicides. Effective fungicides are limited. Previously copper fungicides were used during the autumn at leaf fall and also before budburst to protect leaf scars and bud-scale scars, and carbendazim was applied during the spring and summer. In HDC project TF 144 potential alternative fungicides were evaluated for canker control. None of the products evaluated were more effective than carbendazim, but Octave (prochloraz), Folicur (tebuconazole) and Elvaron Multi (tolylfluanid) were as effective or almost as effective as carbendazim and therefore could be considered as potential replacements. After the first year of this project, use of both carbendazim and tolylfluanid was no longer permitted on apple. Thus effective fungicides for control of canker were limited to captan and pyraclostrobin + boscalid (Bellis) pre-harvest and tebuconazole or copper fungicides post-harvest.

Tree growth and nutrition may also influence canker infection and development. Canker incidence is often greater in poorly growing trees or in trees with excessive growth. It is most likely that a tree that is subject to stress or that is not in growth balance is more prone to canker. Nitrogen is known to encourage canker development but other nutrients, possibly trace elements, may also influence disease development. Which factors are important is not understood.

Up until the 1970s it was normal orchard practice to remove prunings from the orchard and burn them. Any cankers pruned out would therefore have been eliminated from the orchard. Removal and burning of prunings from orchards is now rare, most being pulverised in the tree alleyways. What is not clear is the effect of this practice on canker survival and viability and the likely risk to trees from spores generated by canker debris on the ground. Previous studies by Van der Scheer (1981) and Swinburne and Souter (early 1984), which have focused on canker infection in the trees, have indicated a minimal risk. Despite this there are still concerns among growers. Studies on canker pulverisation in HDC project TF161 showed that pruned out cankers, whether pulverised or unpulverised, could produce perithecia for at least 16 months after being removed from the trees and so could provide inoculum for infection of wounds.

Applying an integrated programme for canker control is costly, especially pruning out cankers and additional fungicide sprays. In addition the intensive fungicide programme can contribute to residues in fruit. Such costs and risks would be considered worthwhile if it resulted in significantly better canker control. However, such an evaluation of the full integrated approach has never been undertaken.

The overall aim of this project is to evaluate a programme in which all the known key methods for canker control are combined, for efficacy in controlling canker. Key methods to be included are:

- Best fungicide programme
- Spray timing
- Summer pruning to remove cankers
- Nutrition

The information generated will be used to produce an HDC Fact sheet on canker control.

Overall objective

To evaluate the efficacy of an integrated programme combining the current best practices in controlling apple canker.

Specific objectives

1. To investigate the effect of an integrated programme on canker incidence on the trees.
2. To investigate the effect of an integrated programme on the incidence of nectria fruit rot in store.

Summary of years 1 and 2

At two orchard sites, both of the cv. Gala on M.9 rootstock, the effect of a full integrated programme for canker control on the incidence of new cankers, nectria fruit rot and shoot growth was compared with that of a standard fungicide programme with no additional specific measures for control of canker. At each site the orchard was divided in half. A standard fungicide programme was applied to one half and a best practice programme, with additional treatments for canker control applied at key timings pre- and post-blossom and at leaf fall, to the other half (Table 1). In addition the plots were sub divided to include removal or non removal of cankers during the summer. The soil was sampled at the start of the trial and leaf samples taken for analysis during the season and additional nutrients applied as necessary. The trials were established in October 2005.

The weather in summer 2006 was relatively dry and not very favourable for spread and infection of nectria. At site 1, the programme of treatments applied to the best practice half of the orchard significantly reduced the numbers of new cankers and the incidence of nectria fruit rot compared to that in the half receiving a standard programme. At site 2 numbers of new cankers were also reduced but not significantly so. The incidence of nectria fruit rot was too low for any effects to be determined. There was no significant effect on shoot growth.

Table 1. Treatments applied in 2006 and 2007 to orchard plots at TL161 EMR (Site 1) and Marsh Gala, Elverton Farm, Teynham (Site 2). Each plot was further split for removal or no removal of cankers in summer

Standard Farm Practice	Canker Best Practice
Standard fungicide programme	Standard fungicide programme + additional sprays for canker at key times as follows: 2-3 at bud burst–bloom (protection of bud scale scars and late frost damage) petal fall petal fall + 2-4 weeks (summer leaf fall) June/July (fruit thinning) August (summer pruning) Sprays for fruit rot at bloom and pre-harvest Folicur pre-leaf fall (October)
Cuprokylt at 10% and 50% leaf fall	Folicur and/or/ carbendazim or Cuprokylt at 10%, 50% and 90% leaf fall

Year 3 - 2008

Materials and Methods

Site

Two orchard sites, both of the cv. Gala, where canker is a problem were chosen for the study. Site one was located at Rocks Farm, East Malling and was an orchard of Gala only on M9 rootstock (TL161 – 30 rows of 27 trees) with a high incidence of nectria canker. Site one was managed by East Malling Research. Site two was located in a commercial orchard of Gala with Cox pollinators on M9 rootstock (Marsh Gala – approx. 22 rows of 80 trees) at Elverton Farm, Teynham. The second site was managed by FAST.

Experimental details

At each site the orchard was divided into half. One half received a standard pesticide programme for control of scab, mildew and pests but with no specific measures for control of canker apart from copper sprays at leaf fall in the autumn. The other half received the same standard pesticide programme but included specific measures for canker control at key timings as detailed in Table 2.

Table 2. Treatments applied in 2008 to orchard plots at TL161 EMR (Site 1) and Marsh Gala, Elverton Farm, Teynham (Site 2). Each plot was further split for removal or no removal of cankers in summer

Standard Farm Practice	Canker Best Practice
Standard fungicide programme	Standard fungicide programme + additional sprays for canker at key times as follows: 2-3 at bud burst –bloom (protection of bud scale scars and late frost damage) petal fall petal fall + 2-4 weeks (summer leaf fall) June/July (fruit thinning) August (summer pruning) Sprays for fruit rot at bloom and pre-harvest Folicur pre-leaf fall (October)
Cuprokylt at 10% and 50% leaf fall	Cuprokylt at 10% and 90% leaf fall, Folicur at 50% leaf fall

At site 1 each half was divided into four sub plots, in two of which cankers were cut out and removed in summer, giving eight plots in total for the trial. At site two each orchard half was sub divided into two plots, cankers being cut out and removed in summer from one sub plot in each half only, giving a total of four sub plots for the trial. A plan of site two showing the four sub plots is included in the appendix.

Pesticide treatments

The standard pesticide programme applied at the two sites was as similar as possible to allow comparisons to be made between the sites. Additional fungicide treatments applied to the canker best practice half were based on Bellis (pyraclostrobin + boscalid), Folicur (tebuconazole) and Captan (captan).

Nutrition

The soil in each half of the orchard at each site was sampled at the start of the trial and analysed to determine fertiliser inputs. Leaf samples for mineral analysis were taken at mouse ear and in August and foliar feeds applied at key stages according to need.

Other orchard treatments

Other treatments such as growth regulators and herbicides were applied as necessary to both halves. Both halves of the orchards were pruned according to commercial practice, but pruning was delayed until after canker assessments were completed. In the best practice half prunings were removed from the orchard and burnt. In the standard practice half prunings were pulverised in the grass alley way and left in the orchard.

Experimental design

Because of the need to have large plots to minimise the influence between treatments, replication was not possible. After discussion with the statistician, to overcome this problem at site one, in each of the 8 sub plots assessments of extension growth and numbers of new cankers were made on 20 marked trees. Similarly for assessment of fruit rot, four bins of fruit were harvested from different areas within each of the eight sub plots. At site 2, assessments of canker and extension growth were made on 10 trees in each of five rows per sub plot. The large sample size allowed some statistical analysis of the data.

Assessments

Cankers

At the start of the trial existing cankers were labelled with paint and recorded. Numbers of new cankers were recorded on the assessment trees in February 2009. Any cankered shoots removed from the assessment trees or plots in summer were also recorded.

Nectria fruit rot

At site one at harvest 2008 four bins of fruit were picked from each of the eight sub plots, clearly labelled and placed in store at 3.5^{o}C; 1.2%O_2, <1%CO_2. The storage conditions are not normally used for Gala, but the higher temperature should encourage the development of nectria rot. At the end of the storage period the bins were removed from store, weighed and graded. The rots were removed during grading, visually identified and weighed and recorded as weight and number of rots per bin.

At site 2 in 2008 the orchard was destined for immediate marketing and not stored. Therefore in order to obtain information on fruit rot incidence a random sample of fruit of ten nets of 50 fruit was harvested from each sub plot of the trial at Elverton Farm and stored at East Malling as above and assessed for rots at the end of the storage period.

Extension growth

Extension growth was measured in winter on 10 shoots on each of the 20 labelled trees in each sub plot at East Malling Research and on each of 10 trees in five rows per sub plot at site two at Elverton Farm.

Weather

Weather conditions were recorded on a weather station located in the orchard or nearby.

Statistical analysis

For all analyses of assessments the treatments were set up as a 2x2 factorial with the factors standard or best practice and removal or non removal of cankers in summer.

Site 1

For numbers of cankers, analysis was done on square root transformations of the counts using ANOVA. Shoot length was analysed as recorded. Each rot variate was analysed after angular transformation. The statistical analysis was where the F-tests for treatments were based on the residual between sub plots within the main plots. This is not strictly correct for practice as there is no true replication but is probably the best approach given the circumstances.

Site 2

For numbers of cankers, analysis was similarly done on counts and square root transformations of the counts using ANOVA. Treatments were tested against the residual based on the variation between rows within sub plots. For extension growth treatments were tested against the differences between tree residual in sub plots.

Results and Discussion

Fungicide treatments

The fungicide programmes applied to plots in 2007/2008 at Site 1 are shown in Table 3.

Table 3. Fungicide treatments applied to standard practice and canker best practice plots in 2007/8 at Site 1 (TL161 EMR). Fungicide rates are shown in brackets where the rates differed between treatments

Timing / Growth stage	Treatment	
	Standard Practice (rate/ha)	**Best Practice (rate/ha)**
2007		
15 October Pre-leaf fall	-	Folicur (0.6 L)
5 November 10% leaf fall	Cuprokylt FL (5.0 L/ha)	Cuprokylt FL (5.0 L/ha)
16 November 50% leaf fall	Cuprokylt FL (5.0 L/ha)	Folicur (0.6 L)
29 November 90% leaf fall	-	Cuprokylt FL (5.0 L/ha)
2008		
29 February Pre-bud burst	Cuprokylt FL (5.0 L/ha)	Cuprokylt FL (5.0 L)
10 March Bud burst	Dithianon + Scala	Dithianon + Scala
18 March	Dithianon + Scala	Dithianon + Scala
27 March	Dithianon + Indar	Dithianon + Indar
2 April	Dithianon + Indar	Dithianon + Indar
11 April Mouse ear/green cluster	Systhane (0.33 L) + Captan (1.0 kg)	Systhane (0.45 L) + Captan (2.0 kg)
23 April Green cluster/pink bud	Systhane (0.33 L)+ Captan (1.0 kg)	Systhane (0.45 L) + Captan (2.0 kg)
28 April	-	Captan (3.4 kg)
6 May Bloom	Systhane (0.33 L) + Captan (0.85 kg)	Systhane (0.33 L)+ Captan (0.85 kg)
9 May	-	Bellis (0.8 kg)
21 May Petal fall	Systhane (0.33 L) + Captan (0.85 kg)	Systhane (0.45 L) + Captan(2.0 kg)
30 May	Systhane (0.33 L) + Captan (0.85 kg)	Systhane (0.33 L) + Captan(2.0 kg)
13 June	Systhane (0.33 L) + Captan (0.85 kg)	Systhane (0.33 L) + Captan (2.0 kg)
26 June	Systhane (0.33 L) + Stroby (0.2 kg) + Captan (3.0 kg)	Systhane (0.33 L) + Stroby (0.2 kg) + Captan (3.0 kg)
4 July	Nimrod (1.1 L) + Captan (2.0 kg)	Nimrod (1.1 L) + Captan (3.4 kg)
17 July	Nimrod (1.1 L) + Captan (1.5 kg)	Nimrod (1.1 L) + Captan (3.4 kg
29 July	Nimrod (1.1 L)	Nimrod (1.1 L) + Captan (3.4 kg
18 August	-	Bellis (0.8 kg)

The additional treatments applied to the best practice half of the orchard were based on full rate captan (3.4 kg/ha) with a spray of Bellis (pyraclostrobin + boscalid) during blossom and Folicur (tebuconazole) post-harvest.

A similar fungicide programme of additional treatments for canker was applied to plots at Site 2.

Soil and leaf analysis

Analysis of soil and leaf samples from standard and best practice plots were satisfactory so no additional nutrients apart from the normal practice were applied at either site in 2008.

Numbers of new cankers

Site 1

Numbers of new cankers were recorded on the 20 labelled trees in each sub plot in February 2009 as those associated with pruning cuts, leaf scars, bud scale scars or shoot base. The cankers removed from the labelled trees in summer 2008 were included in the final counts for numbers of cankers. The mean number of cankers per tree is shown in Table 4.

Table 4. Mean number of new cankers per tree (square root transformed) recorded in February 2009 (including cankers removed in summer 2008) as leaf scars, pruning wounds, shoot base in plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 1 (TL161 Gala orchard, EMR). Figures in brackets are back transformed data.

Main plot treatment	No summer canker removal	Summer canker removal	Overall mean
Standard programme	2.5 (6.2)	2.7 (7.3)	2.6 (6.7)
Best practice programme	1.1 (1.3)	1.4 (1.8)	1.2 (1.5)
Overall mean	1.8 (3.2)	2.0 (4.1)	

Statistical comparisons

Item	Standard v. Best practice	Removal v. no canker removal	Practice x canker removal
F Probability	0.007	0.461	0.963
SED (4 df)	0.267	0.267	0.377
LSD (p=0.05)	0.741	0.741	1.047

The mean number of new cankers per tree was significantly reduced (p=0.007) by the treatments applied in autumn 2008 in the best practice half of the orchard (mean of 6.7 cankers per tree in standard practice compared to 1.5 per tree in best practice). These cankers were most likely the result of infection of wounds by nectria spores (conidia or ascospores) and therefore likely to be influenced by any treatments applied. As expected there was no significant effect of summer canker removal on numbers of new cankers. This treatment should have most effect on the incidence of nectria fruit rot.

In summer 2008 less than one canker per tree was removed from the best practice half compared to almost three cankers per tree in the standard practice half. The cankers removed during summer 2008 were the result of infections during autumn 2007.

Site 2

The incidence of canker in Marsh Gala has decreased since the trial started such that numbers of new cankers recorded in summer 2008 were low. The mean number of cankers per tree recorded in July 2008 is shown in Table 5. There were no obvious effects of the treatments on numbers of cankers.

Table 5. Total number of cankers per tree recorded in July 2008 in plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 2 (Marsh Gala, Elverton Farm, Teynham)

Main plot treatment	No summer canker removal	Summer canker removal	Overall mean
Standard programme	0.14	0.08	0.11
Best practice programme	0.12	0.14	0.13
Overall mean	0.13	0.11	

Nectria fruit rot

Site 1

Four bins of fruit were harvested per sub plot on September 2008 and stored until 11 February 2009. The rainfall in April and May 2008 (Table 6) was above average and very favourable for infection of fruit by *Nectria galligena*.

Table 6. Monthly rainfall (mm) recorded at EMR in April to September in 2006 and 2007, compared to 50 year average

Month	2006	2007	2008	50 year average
April	70.8	0.8	50.0	44.5
May	77.0	85.0	67.8	45.8
June	8.4	74.6	22.2	49.7
July	11.0	119.2	55.8	46.4
August	40.8	40.8	60.8	52.0
September	42.0	25.4	50.8	63.7

The subsequent weather up until harvest continued wet with above average rainfall and was therefore very favourable for fruit infection. The incidence of rotting per bin was therefore relatively high and varied from 0.4% to 4.6%. Most of the rotting was due to nectria. Mean % total losses per bin due to rots and to nectria are shown in Table 7.

Table 7. Mean % losses due to rots (angular transformed) following storage of fruit (at 3.5^{o}C; 1.2%O_2, <1%CO_2) harvested in September 2008 from plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 1 (TL161 Gala orchard, EMR). Figures in brackets are back-transformed data

Main plot treatment	No summer canker removal		Summer canker removal		Overall mean	
	Nectria	Total rot	Nectria	Total rot	Nectria	Total rot
Standard programme	8.5 (2.2)	9.2 (2.5)	8.6 (2.2)	9.4 (2.7)	8.5 (2.2)	9.3 (2.6)
Best practice programme	5.6 (1.0)	7.7 (1.8)	7.2 (1.6)	8.5 (2.2)	6.4 (1.2)	8.1 (2.0)
Overall mean	7.1 (1.5)	8.5 (2.2)	7.9 (1.9)	9.0 (2.4)		

Statistical comparisons

Item	Standard v. Best practice		Removal v. no canker removal		Practice x canker removal	
	Nectria	Total rot	Nectria	Total rot	Nectria	Total rot
F Probability	0.131	0.288	0.521	0.631	0.541	0.800
SED (4 df)	1.137	0.973	1.137	0.973	1.609	1.376
LSD (p=0.05)	3.158	2.701	3.158	2.701	4.466	3.820

There was no significant difference in the incidence of both total rots and nectria rots (p=0.131 & 0.288 for nectria rots and total rots) in bins harvested from plots receiving the best practice programme compared to standard practice. There was no significant effect of removing cankers during the summer on the incidence of rotting

(p=0.521). Cankers present on one and two year old wood generally sporulate during the summer months and spores (conidia) are spread from these by rain splash to infect fruit. Therefore removal of these during summer might be expected to reduce the amount of inoculum and hence reduce rotting.

The wet conditions in June and July should have been conducive to nectria sporulation and spread. So removal of cankers on young wood would have been expected to reduce inoculum and hence the incidence of nectria rot. However, evidence from nectria inoculation studies conducted as part of Defra-funded project HH3232STF has shown that fruit are most susceptible to infection in late bloom and early fruitlet and then decline in susceptibility with a slight increase in susceptibility just prior to harvest. Cankers were not removed until July and August. It is possible that removal of cankers earlier i.e. soon after blossom may have resulted in significant effects on nectria rot incidence.

Site 2

Ten nets of 50 fruit were sampled separately from the sub plots in September and placed in cold store as above at EMR. Rot incidence was assessed on 29 March 2009. Total losses due to rots ranged from 4% to more than 6% (Table 8). Most of this was due to penicillium and brown rot. Rotting due to nectria ranged from 0.4 to 2.4%. Least rots were recorded in the canker best practice plots. There was no obvious effect of summer canker removal on nectria rot incidence.

Table 8. Percent losses due to rots following storage of fruit (at 3.5^{o}C; 1.2%O_2, <1%CO_2) harvested in September 2008 from plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 2 (Marsh Gala, Elverton Farm, Teynham).

Main plot treatment	No summer canker removal		Summer canker removal		Overall mean	
	Nectria	Total rot	Nectria	Total rot	Nectria	Total rot
Standard programme	1.8	4.0	2.4	6.2	2.1	5.1
Best practice programme	0.4	4.8	0.6	5.2	0.5	5.3
Overall mean	1.1	4.4	1.5	5.7		

Extension growth

Site 1

One and two year-old extension growth was measured in January 2008 and one year-old extension growth measured in January 2009 (Tables 9 and 10).

Table 9. Mean annual shoot growth (cm) in 2006 on trees from plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 1 (TL161 Gala orchard, EMR)

Main plot treatment	No summer canker removal	Summer canker removal	Overall mean
Standard programme	25.0	26.4	25.7
Best practice programme	31.5	27.9	29.7
Overall mean	28.2	27.2	

Statistical comparisons

Item	Standard v. Best practice	Removal v. no canker removal	Practice x canker removal
F Probability	0.186	0.704	0.375
SED (4 df)	2.511	2.511	3.55
LSD (p=0.05)	6.97	6.97	9.857

Table 10. Mean annual shoot growth (cm) in 2007 on trees from plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 1 (TL161 Gala orchard, EMR)

Main plot treatment	No summer canker removal	Summer canker removal	Overall mean
Standard programme	35.2	32.2	33.7
Best practice programme	34.2	30.4	32.3
Overall mean	34.7	31.3	

Statistical comparisons

Item	Standard v. Best practice	Removal v. no canker removal	Practice x canker removal
F Probability	0.527	0.154	0.846
SED (4 df)	1.952	1.952	2.761
LSD (p=0.05)	5.420	5.420	7.665

There was no significant effect of canker best practice treatments on shoot growth in 2006 and 2007. In 2008 shoot growth (Table 11) was significantly better on trees receiving the standard farm programme compared to those in the best practice plots.

Table 11. Mean annual shoot growth (cm) in 2008 on trees from plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 1 (TL161 Gala orchard, EMR)

Main plot treatment	No summer canker removal	Summer canker removal	Overall mean
Standard programme	37.8	40.0	38.9
Best practice programme	33.3	31.7	32.5
Overall mean	35.6	35.8	

Statistical comparisons

Item	Standard v. Best practice	Removal v. no canker removal	Practice x canker removal
F Probability	0.026	0.902	0.368
SED (4 df)	1.865	1.865	2.638
LSD (p=0.05)	5.178	5.178	7.323

It would be expected that trees with significant canker would be less vigorous than healthy trees. Controlling canker might be expected to improve tree growth so a significant reduction in growth was unexpected. This might be due to the intensive fungicide programme applied to the trees in the best practice half of the orchard. Folicur (tebuconazole), applied to trees post-harvest prior to leaf fall, is a triazole and has been shown to exhibit a growth regulatory effect in other crops. Whether its use post- harvest could have an effect on shoot growth the following season is not known.

Site 2

Extension growth was measured on 10 one year-old shoots on each of 50 trees per plot in January 2009 (Table 12). There were no obvious effects of treatments on shoot length.

Table 12. Mean annual shoot growth (cm) in 2008 on trees from plots receiving a standard fungicide or best practice programme with and without summer canker removal at Site 2 (Marsh Gala, Elverton Farm, Teynham)

Main plot treatment	No summer canker removal	Summer canker removal	Overall mean
Standard programme	70.8	70.7	70.8
Best practice programme	69.9	76	73.0
Overall mean	70.4	73.4	

Conclusions

- The fungicide programme applied in the best practice half of the orchard reduced the incidence of nectria fruit rot at site 1 (TL161, EMR) and site 2 (Marsh Gala, Elverton Farm, Teynham) compared to the half of the orchard that received the standard farm programme although the reduction in rotting was not significant
- The fungicide programme applied in the best practice half of the orchard reduced the numbers of new cankers per tree at site 1 (TL161, EMR) compared to the half of the orchard that received the standard farm programme
- Numbers of new cankers recorded at site 2 (Marsh Gala, Elverton Farm) were too low for meaningful comparisons to be made
- There was no effect of treatment on shoot growth at site 1 in 2006 and 2007. In 2008 shoot growth was significantly greater on trees receiving the standard farm programme
- There was no effect of treatment on shoot growth in 2008 at site 2

Future work

The results of the three year study clearly show that application of an intensive integrated programme for canker control resulted in a significant reduction in numbers of new cankers and nectria fruit rot. However, such an intensive programme is costly and will result in detectable residues in the fruit at harvest. A more targeted fungicide programme may control canker with the minimum risk of residues in the fruit. Further research is needed to determine whether the more targeted fungicide programme would be as effective.

Technology transfer

Results from the project were reported at the National Fruit Show in October 2008. An article was produced for *HDC News* in 2008.

References

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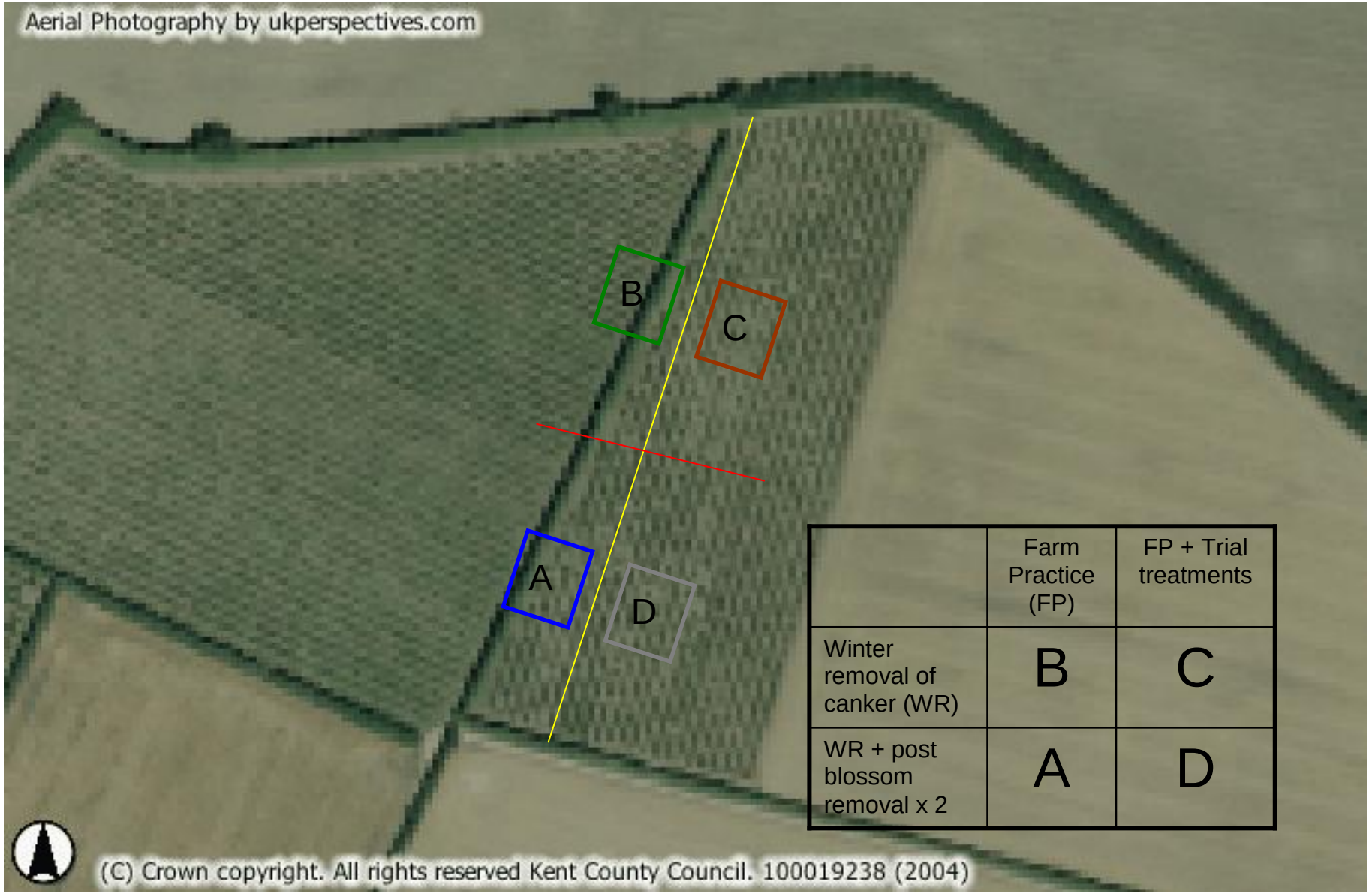
APPENDIX



	Farm Practice (FP)	FP + Trial treatments
Winter removal of canker (WR)	B	C
WR + post blossom removal x 2	A	D