Project title:	Apple - Sustainable management of storage rots
Project number:	TF 193
Project leader:	Dr Angela M Berrie
Report:	Annual report, November 2010
Previous report:	None
Key staff:	Dr Angela M Berrie
Location of project:	East Malling Research New Road East Malling, Kent ME19 6BJ
Project co-ordinator:	
Date project commenced:	1 April 2009
Date project completed (or expected completion date):	31 March 2011
Report date:	November 2010
Key words:	Apple, storage rot, fungicide, brown rot, *Botrytis*, *Nectria*, *Penicillium*, *Gloeosporium*

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

AUTHENTICATION

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

Dr A M Berrie
Research Leader
East Malling Research

Signature .... Date: ....

Report authorised by:

Dr Christopher Atkinson
Head of Science
East Malling Research

Signature .... Date: 7 December 2010

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GROWER SUMMARY

Headline

- Despite the above average rainfall in 2008, the incidence of rots in stored apples and pears was on average below 2%, with brown rot the principal rot in apples and *Botrytis* in pears.

Background and expected deliverables

What are the main rots responsible for losses in stored apples?

Fungal rots can result in significant losses in stored apples, particularly in fruit stored beyond January. They can also lead to an increase in grading costs. Successful control of storage rots depends on a clear understanding of the rots to be controlled. The current strategy is based on rot surveys from the 1990s when nectria, *Botrytis*, brown rot, *Penicillium, Phytophthora* and *Gloeosporium* were identified as the main rots in apple. Since then the rot profile may have changed. Rot trials in orchards at EMR have indicated an increase in incidence of rots such as *Botryosphaeria sp.*, *Phomopsis sp.* and *Colletotrichum sp.* in stored fruit. Whether these are also of increased prevalence in commercial orchards is not known, but it is important to understand their incidence as rot control strategies may need to be modified. Growers often report increased rots during fruit grading but rarely identify the rots present. 2008 was exceptionally wet from blossom to harvest and consequently produced a particularly high risk for rot infection of apple. This project provides the opportunity to re-evaluate rot incidence and to assess the success of the current rot control strategy on commercial farms.

Storage rot control

Until recently, control of storage rots was mainly achieved by the use of post-harvest fungicide drenches that were generally applied regardless of need**.** Use of post-harvest treatments has declined due to a combination of factors including reduced efficacy due to fungicide resistance, non-availability of fungicides and pressure by consumers and markets to stop their use**.** An alternative strategy was developed for rot control based on rot risk assessment to determine whether treatment was needed. The assessment also provides guidance on the need for orchard sprays requirement for selective picking at harvest and also to decide if early marketing of fruit is necessary where a high risk of rotting is identified**.** Pre-harvest orchard sprays and selective picking have been successful alternative treatments for control of phytophthora and brown rot, but control of other rots such as nectria was based on identifying problem orchards and marketing fruit early. In Defra project HH3232STF the efficacy of treatments applied at blossom and petal fall on rot control, in particular nectria rot, were evaluated. This treatment timing was based on inoculation studies which showed that fruit was most susceptible to *Nectria galligena* at blossom and petal fall. Fruit susceptibility declined in summer but increased slightly near harvest**.** The early season treatments were shown to reduce nectria fruit rot. However, there is a need to compare early season treatments with pre-harvest treatments to establish whether additional late sprays are important in controlling rots. These comparisons were not included in the Defra work.

The concept of rot risk assessment was introduced via the Apple Best Practice Guide in 2001. HDC-funded training courses on rot risk assessment were conducted in 2005 and numerous presentations on storage rots have been made at various grower meetings. Despite this, when wet conditions prevail during spring and summer many growers resort to late season sprays and post-harvest treatments. Pre-harvest fungicides applied for rot control are generally applied 2-4 weeks before harvest resulting in a high risk of residues in the fruit. If fungicide treatments pre-harvest were shown to be of no additional benefit, then such treatments could be avoided to reduce the risk of pesticide residues in the fruit. Similarly if other control measures such as selective picking were shown to be effective in controlling phytophthora and brown rot then growers would be encouraged to adopt them.

There is therefore a need to evaluate early season treatments compared to pre-harvest treatments and integrated control based on rot risk assessment and selective picking.

Summary of the project and main conclusions

Rot survey

Seven packhouses were visited weekly from January-March in 2009. Three were located in East Kent and four south of Maidstone. Visits were also made to a packhouse in Hereford. At each visit at least 100 rotted fruit were removed from the rot bin or collected from the grader of fruit that was being graded at the time of the visit. Rots were identified visually and numbers recorded.

Actual losses in Cox and Gala due to rots were very low, less than 2% losses overall, range <0.5-5. Most losses were attributed to brown rot (*Monilinia fructigena*) which accounted for over a third of losses. *Nectria* accounted for about 20% of losses with *Botrytis* and *Gloeosporium* also important. *Phytophthora*, *Colletotrichum, Fusarium, Botryosphaeria*, *Phomopsis* and *Mucor* were also recorded at low incidence.

In Braeburn and Jazz, harvested in October, losses due to rots were negligible. On average most losses were due to brown rot. *Phytophthora, Botrytis, Penicillium*, *Nectria, Gloeosporium, Fusarium* and *Muco*r rots were also recorded.

In Bramley, losses due to rots were on average 1.8% (range <1-4%). As with the other varieties, on average, most of the losses (over 40%) were accounted for by brown rot. *Botrytis, Penicillium, Nectria, Fusarium* and *Phomopsis* rots were also present. Much of the *Fusarium* was present as cheek rots which appeared to have originated from the core.

Losses due to rots in Conference and Comice were on average 1.3% (range 0.5-2.5). Over three quarters of this rotting was accounted for by *Botrytis* and brown rot. The incidence of other rots was very low.

Control of storage rots

In a large plot replicated orchard trial, fungicide treatments of Captan or Bellis (pyraclostrobin + boscalid) applied at blossom and / or pre-harvest were compared to an untreated control for control of storage rots. An additional treatment compared fungicides applied at blossom coupled with selective picking at harvest versus pre-harvest sprays. With selective picking, thefruit pickers at harvest were instructed to place only undamaged fruit in the bin and to exclude all fruit below knee height (<0.5 metres above the ground) from the bin. This minimizes the risk of introducing fungal rots such as brown rot, *Penicillium* rot (damaged fruit) or *Phytophthora* rot (low hanging fruit) into the bin. In the other treatments fruit was harvested as in commercial practice and including low hanging fruit. Fruit was harvested on 10 September and one bin of apples picked per plot. Bins were stored in controlled atmosphere at Cox storage conditions (3.5^oC, $1\%O_2<1\%CO_2$) until March and the rots assessed on removal from store.

The incidence of storage rots was low with just over 2% rotting in total in untreated plots. Overall there was significantly more rotting in untreated plots compared to treated plots. Treatments 3 (pre-harvest sprays only) and 4 (blossom sprays + pre-harvest sprays) had significantly less rots in total than the untreated. The main rots recorded were brown rot, *Botrytis*, *Penicillium*, *Nectria*, *Phomopsis*, *Botryosphaeria* and *Colletotrichum.* Overall significantly less rotting was recorded in treated plots compared to untreated plots for *Nectria*, *Phomopsis* and *Botryosphaeria,* but the incidence of rots was too low for differences between individual treatments to be identified. There were no significant effects of treatments on brown rot, *Botrytis*, *Penicillium* or *Colletotrichum.*

Financial benefits

Significant losses can result from rotting in store. Use of post-harvest fungicides is no longer an option for control. Effective control depends on knowing which rots require control measures and when to apply them. It is clear from the last two seasons when rot risk has been higher due to wet weather in summer that many growers prefer to spray regardless of need rather than make treatment decisions based on risk assessments. This project will identify the main rots responsible for losses and provide information on the success of current methods used by the industry for rot control. It will also evaluate new rot control strategies. The information generated should give growers the confidence for a new approach to rot control.

Action points for growers

- The project is at an early stage and there are no action points to report at present.

SCIENCE SECTION

Introduction

Storage rot incidence

Fungal rots can result in significant losses in stored apples, particularly in fruit stored beyond January, and increase grading costs. Successful control of storage rots depends on a clear understanding of the rots to be controlled. The current strategy is based on rot surveys from the 1990s when *n*ectria, *b*otrytis, brown rot, *p*enicillium*, p*hytophthora and *g*loeosporium were identified as the main rots in apple. Since then the rot profile may have changed. Rot trials in orchards at EMR have indicated an increase in incidence of rots such as *Botryosphaeria sp.*, *Phomopsis sp.* and *Colletotrichum sp.* in stored fruit. Whether these are also of increased prevalence in commercial orchards is not known, but it is important to know their incidence as rot control strategies may need to be modified. Growers often report increased rots during fruit grading but rarely identify the rots present. 2008 was exceptionally wet from blossom to harvest and consequently produced a particularly high risk for rot infection of apple. This project provides the opportunity to re-evaluate rot incidence and to assess the success of the current rot control strategy on commercial farms.

Storage rot control

Until recently, control of storage rots was mainly achieved by the use of post-harvest fungicide drenches that were generally applied regardless of need**.** Use of post-harvest treatments has declined due to a combination of factors including reduced efficacy due to fungicide resistance, non-availability of fungicides and dislike of residues by consumers and hence markets**.** An alternative strategy was developed for rot control based on rot risk assessment to determine whether treatment was needed, orchard sprays where necessary, selective picking at harvest and early marketing of fruit where a high risk of rotting was identified**.** Pre-harvest orchard sprays and selective picking were successful alternative treatments for control of phytophthora and brown rot, but control of other rots such as nectria was based on identifying problem orchards and early marketing of fruit. In Defra project HH3232STF the efficacy of treatments applied at blossom and petal fall on rot control, in particular nectria rot were evaluated. This treatment timing was based on inoculation studies which showed that fruit was most susceptible to *Nectria galligena* at blossom and petal fall (Xu & Robinson, 2010). Fruit susceptibility declined in summer and then increased slightly near harvest**.** The early season treatments were shown to reduce nectria fruit rot. However, there is a need to compare early season treatments with pre-harvest treatments to establish whether additional late sprays are important in controlling rots. These comparisons were not included in the Defra work.

The concept of rot risk assessment was introduced via the Apple Best Practice Guide in 2001. HDC-funded training courses on rot risk assessment were conducted in 2005 and numerous presentations on storage rots have been made at various grower meetings. Despite this, when wet conditions prevail during spring and summer many growers resort to late season sprays and post-harvest treatments. Pre-harvest fungicides applied for rot control are generally applied 2-4 weeks before harvest with a high risk of consequent residues in the fruit. If fungicide treatments pre-harvest were shown to be of no additional benefit then such treatments could be avoided and the risk of pesticide residues in the fruit reduced. Similarly if other control measures such as selective picking were shown to be effective in controlling phytophthora and brown rot then growers would be encouraged to adopt them. There is therefore a need to evaluate early season treatments compared to pre-harvest treatments and integrated control based on rot risk assessment and selective picking.

Overall aim of project

To develop a sustainable, cost effective system for the control of storage rots in apple

Specific Objectives

1. To identify losses due to rots in commercial orchards and the main fungi responsible for the rots
2. To evaluate the efficacy of fungicides applied at blossom and petal fall compared to sprays applied pre-harvest and treatments based on selective picking for control of storage rots

Materials and methods

Storage rot incidence

Seven packhouses (Table 1) were visited weekly from January-March in 2009. Three were located in East Kent and four south of Maidstone. Visits were also made to a packhouse in Hereford. At each visit at least 100 rotted fruit were removed from the rot bin or collected from the grader from the batch of fruit that was being graded at the time of the visit. Rots were identified visually and numbers recorded. Unknown rots were taken back to the laboratory and isolated on to Potato Dextrose Agar (PDA) and identified from spores or characteristic growth in culture.

Table 1. Fruit packhouses visited weekly in January – March 2009

Packhouse	**Location**	**Number times visited**
Newmafruit Farms Ltd	Howfield Farm, Chartham Hatch, Kent	5
F W Mansfield & Sons Ltd	Nickle Farm, Chartham, Kent	5
A R Neaves & Sons Ltd	Little Sharsted Farm, Doddington, Kent	6
The Breach	Goudhurst, Kent	5
G H Chambers	Northiam Farm, Horsmonden, Kent	4
Bardsley & Sons	River Farm, Staplehurst, Kent	4
J L Baxter & Son Ltd	Amsbury Farm, Hunton, Kent	5
Wye Fruit Ltd	Ledbury, Herefordshire	1

Control of storage rots

Site - East Malling Research

<u>Orchard details</u>

The trial was located in orchard TL109, located at Rocks Farm, East Malling Research. The orchard was planted in 1984 and is 0.73 ha in size and consists of Cox on MM106 rootstock with Discovery and Spartan pollinators with 3.5 m between trees in the row and 5.0 m between rows. There is a moderate incidence of *nectria* canker in the orchard, which also has a history of brown rot and other storage diseases.

Plot size and experimental design

Each plot consisted of three rows of five Cox trees (15 trees in total). The yield from these should be sufficient to fill one or two bulk bins per plot. Treatments were replicated three times in a randomised block design.

Treatments

The treatments in Table 2 were applied to plots. Fungicide treatments were either applied at blossom and / or pre-harvest. Selective picking at harvest was included in place of pre-harvest sprays in treatment 5. In this treatment fruit pickers at harvest were instructed to place only undamaged fruit in the bin and to exclude all fruit below knee height (<0.5 metres above the ground) from the bin. This minimizes the risk of introducing fungal rots such as brown rot, penicillium rot (damaged fruit) or phytophthora rot (low hanging fruit) into the bin. In treatments 1-4 fruit was harvested as in commercial practice and including low hanging fruit.

A standard programme for scab and mildew control was applied to the orchard from bud burst up to the start of treatments. Systhane (myclobutanil) or Nimrod (bupirimate) was applied to all plots for control of powdery mildew. Insecticides were applied to all plots as necessary. Nutrient sprays (including full calcium programme) was also applied to all plots.

All treatments were applied by tractor trailed orchard sprayer at 200 L/ha.

Assessments

Growth stages at application

The phenological stage was recorded at each spray application timing.

Rots

The incidence of nectria eye rot was recorded in June. The risk and incidence of other rots in the plots was assessed pre-harvest as necessary.

Harvest

At harvest one or two bins of apples were harvested per plot. Fruit from plots in treatment 5 (plots 1, 6, 11) were selectively picked i.e. no low hanging fruit or damaged fruit picked. Fruit in all other plots were picked as normal commercial picking. Bins were stored in controlled atmosphere stores at Cox storage conditions (3.5^{o}C, 1%O_2<1%CO_2) until March.

Post store rot assessment

At the end of the storage period the bins were graded individually, the rots removed and identified. Each bin was weighed prior to and after grading and the weight of rots from each bin was also recorded. The rots were identified visually where possible and also weighed. Unidentified rots were cultured on to PDA and identified from spores or characteristic culture growth.

Table 2. Fungicide programmes and treatments to be applied to TL109, EMR in 2009

Treatment	**Active ingredient**	**Product rate per ha**	**Timing**
1 untreated	-	-	-
2 Captan (1 spray) Bellis (1 spray)	captan pyraclostrobin + boscalid	3.4kg 0.8 kg	Full bloom Full bloom + 10 days
3 Captan (1 spray) Bellis (1 spray)	captan pyraclostrobin + boscalid	3.4kg 0.8 kg	4 weeks and 2 weeks pre-harvest
4 Captan (1 spray) Bellis (1 spray)	captan pyraclostrobin + boscalid	3.4kg 0.8 kg	Full bloom Full bloom + 10 days
Captan (1 spray) Bellis (1 spray)	captan pyraclostrobin + boscalid	3.4kg 0.8 kg	4 weeks and 2 weeks pre-harvest
5 Captan (1 spray) Bellis (1 spray)	captan pyraclostrobin + boscalid	3.4kg 0.8 kg	Full bloom Full bloom + 10 days Selective picking at harvest

Results and discussion

Storage rot incidence

Apple – Cox, Gala, Egremont Russet

In the rot survey conducted in January-March 2009 (Tables 5 & 7), despite the wet weather in spring and summer 2008 (Table 3), actual losses due to rots were very low, less than 2% losses overall, range <0.5-5. Most losses were due to brown rot (*Monilinia fructigena*) which accounted for over a third of losses. Nectria accounted for about 20% of losses with *b*otrytis and *g*loeosporium also being important. Fruit picked in the first half of September was at risk from *p*hytophthora (>20 mm rain in 15 days prior to harvest) (Table 4). A low incidence of this rot was present in both Cox and Gala. Colletotrichum, *f*usarium, *b*otryosphaeria, *p*homopsis and *m*ucor were also recorded.

Apple – Braeburn, Jazz

In Braeburn and Jazz, harvested in October, (Table 6) losses due to rots were negligible, apart from one sample of Braeburn where losses were almost 5%. On average most losses were due to brown rot. Fruit picked in October was also at risk from *p*hytophthora (Table 4) which was recorded at low incidence in 4 of the 13 samples. Botrytis, *p*enicillium, *n*ectria, *g*loeosporium, *f*usarium and *muco*r were also recorded.

Apple – Bramley

Losses due to rots (Table 8) were on average 1.8% (range <1-4%). As with the other cultivars, on average, most of the losses (over 40%) were accounted for by brown rot. Botrytis, *p*enicillium, *n*ectria, *f*usarium and *phomopsis* were also present. Much of the *f*usarium was present as cheek rots which appeared to have originated from the core. In one sample of Bramley assessed in February at Wye Fruit (originated from Wisbech, Cambs.) (Table 8) most rotting was accounted for by *c*olletotrichum and *f*usarium, both of which appeared to originate from the core.

Pear – Conference and Comice

Losses due to rots were on average 1.3% (range 0.5-2.5) (Table 9). Over three quarters of this rotting was accounted for by *b*otrytis and brown rot. The incidence of other rots was very low.

General discussion

In rot surveys conducted between 1995 and 2000 (Berrie, 1997) losses due to rots ranged from an average of 1.5 to 5.6%. Most losses were due to brown rot (*Monilinia fructigena*) but botrytis eye rot was also important and nectria rot increasing in significance from 1998-2000. Phytophthora rot was important in 1995 when there was significant rain fall during the harvest period. In the survey conducted here average losses were generally low - <2% for Cox, Gala, Bramley and Egremont Russet and exceptionally low for the newer cultivars Braeburn and Jazz which were not present in the earlier surveys.

In 1995-2000 most apples would have been treated with a post-harvest fungicide prior to storage. Since such treatments are now no longer available losses in the current survey would therefore have been expected to be on average higher, especially given the favourable wet summer of 2008 (Table 3). Reasons for these low losses could be due to several factors including fungicide application in late blossom to control nectria rot or pre-harvest and better management of fruit at harvest.

As in the earlier surveys, most rotting was caused by brown rot. *Nectria* rot was also causing significant losses. The incidence of gloeosporium rots was low, although this is one of the most important causes of losses in store in apples in other parts of Europe. Other rots such as *c*olletotrichum, *f*usarium, *b*otryosphaeria and phomopsis, present at trace incidence in 1995-2000 survey, have increased in incidence especially on Bramley. Bramley is stored from September – August. The survey reported here did not continue after March. However, significant losses in Bramley due to rots are reported from packhouses in the later stored fruit. This will be investigated in 2010.

Losses due to rots in pears were low - <2%. *Botrytis* and brown rot were the main cause of losses, similar to the results from earlier surveys.

Table 3. Monthly rainfall (mm) recorded at EMR in March to September in 2006, 2007, 2008 and 2009, compared to 50 year average

Month	2006	2007	2008	2009	50 year average
March	40.4	51.0	97.8	41.2	44.3
April	70.8	0.8	50.0	34.4	44.5
May	77.0	85.0	67.8	24.2	45.8
June	8.4	67.4	22.2	27.2	49.7
July	11.0	117.8	55.8	60.0	46.4
August	40.8	40.8	60.8	20.8	52.0
September	42.0	25.4	50.8	26.4	63.7

Table 4. Risk of phytophthora rot in 2008 – rainfall in 15 days pre-harvest, >20 mm = risk

Harvest date	Rain in 15 days pre-harvest
1 September	15.6
5 September	29.8
10 September	42.0
15 September	42.6
20 September	15.8
25 September	4.4
30 September	8.2
5 October	25.2
10 October	28.0
15 October	25.4
20 October	18.6
31 October	28.8

Table 5. Losses due to rots and rot incidence in apples cv. Cox assessed during grading at various packhouses in Kent and Herefordshire in January-March 2009

Packhouse	Date assessed	Date picked	Brown rot	Botrytis	Phytophthora	Penicillium	Nectria	Gloeosporium	Colletotrichum	Fusarium	Mucor	Botryosphaeria	Phomopsis	% Loss estimated
Amsbury	22 Jan	?	15	12	0	7	24	42	0	0	0	0	0	<1
Amsbury	28 Jan	?	0	2	0	12	57	26	0	3	0	0	0	?
Chambers	28 Jan	?	33	15	0	8	22	22	0	0	0	0	0	1.0
River Farm	28 Jan	?	84	2	1	2	3	0	0	0	7	1	0	2.0
Neaves	29 Jan	20 Sep	21	50	0	21	4	0	0	4	0	0	0	<0.5
Jan mean			**30.6**	**16.2**	**0.2**	**10.0**	**22.0**	**18.0**	**0**	**1.4**	**1.4**	**0.2**	**0**	**1.0**
River Farm	4 Feb	?	72	11	0	7	6	1	2	0	0	1	0	3.0
Chambers	4 Feb	?	48	18	0	6	17	10	0	1	0	0	0	1.0
Neaves	5 Feb	12 Sep	36	25	12	6	17	4	0	0	0	0	0	<0.5
NFF	5 Feb	8 Sep	75	9	4	3	6	3	0	0	0	0	0	1.5
Mansfield	5 Feb	13 Sep	42	6	5	2	42	1	0	0	1	1	0	2.5
Neaves	12 Feb	5 Sep	23	21	2	2	29	23	0	0	0	0	0	0.5
Neaves	12 Feb	5 Sep	3	16	3	1	56	20	0	0	1	0	0	0.5
The Breach	18 Feb	25 Sep	70	0	0	5	20	0	0	0	5	0	0	1.5
Neave	19 Feb	?	10	14	0	12	54	8	0	0	0	1	1	1.0
Neave	19 Feb	?	44	0	0	22	34	0	0	0	0	0	0	1.0

Table 5. Losses due to rots and rot incidence in apples cv. Cox assessed during grading at various packhouses in Kent and Herefordshire in January-March 2009 ...*continued*

Packhouse	Date assessed	Date picked	Brown rot	Botrytis	Phytophthora	Penicillium	Nectria	Gloeosporium	Colletotrichum	Fusarium	Mucor	Botryosphaeria	Phomopsis	% Loss estimated
Mansfield	19 Feb	?	21	12	0	4	63	0	0	0	0	0	0	5.0
NFF	19 Feb	8 Sep	20	17.1	8.6	14.3	11.4	7.1	20.0	1.4	0	0	0	2.5
Mansfield	26 Feb	?	20	9	3	10	46	10	0	0	0	0	2	4.0
NFF	26 Feb	4 Sep	12	32	2	5	2	47	0	0	0	0	0	3.0
Neave	26 Feb	17 Sep	18	7	0	6	19	43	3	2	0	2	0	3.5
Feb mean			**34.3**	**3.1**	**2.6**	**7.0**	**28.2**	**11.8**	**1.7**	**0.3**	**0.5**	**0.3**	**0.2**	**2.1**
Neave	5 Mar	15 Sep	14	12	0	6	68	0	0	0	0	0	0	2.5
NFF	5 Mar	8 Sep	29	21	0	19	22	7	0	0	2	0	0	1.5
Mansfield	5 Mar	?	31	33	0	8	24	1	3	0	1	0	0	1.5
March mean			**24.7**	**22.0**	**0**	**11.0**	**38.0**	**2.7**	**1.0**	**0**	**1.0**	**0**	**0**	**1.8**
Overall mean			**32.2**	**15.0**	**1.8**	**8.2**	**28.1**	**12.2**	**1.2**	**0.4**	**0.8**	**0.3**	**0.1**	**1.8 (<0.5-5)**
Wye Fruit	24 Feb	?	10	23	12	3	16	31	0	0	0	0	5	<1
Wye Fruit	24 Feb	?	37	4	2	0	3	54	0	0	0	0	1	<1
Wye Fruit	24 Feb	?	8	1	2	2	14	60	0	0	0	1	12	<1
Overall mean			**18.3**	**9.3**	**5.3**	**1.7**	**11.0**	**48.3**	**0**	**0**	**0**	**0.3**	**6.0**	**<1**

Table 6. Losses due to rots and rot incidence in apples cvs Jazz and Braeburn assessed during grading at various packhouses in Kent in January-March 2009

Packhouse	Date assessed	Date picked	Brown rot	Botrytis	Phytophthora	Penicillium	Nectria	Gloeosporium	Colletotrichum	Fusarium	Mucor	Botryosphaeria	Phomopsis	% Loss estimated
Jazz														
Amsbury	4 Feb	?	26.7	23.3	1.7	3.3	30	15	0	0	0	0	0	<1
Mansfield	5 Feb	?	0	0	0	0	0	0	0	0	0	0	0	0
Mansfield	12 Feb	?	50	50	0	0	0	0	0	0	0	0	0	0.1
Mansfield	19 Feb	?	50	50	0	0	0	0	0	0	0	0	0	0.1
Mansfield	26 Feb	?	40	30	0	30	0	0	0	0	0	0	0	0.1
Mean			**33.3**	**30.7**	**0.3**	**6.7**	**6.0**	**3.0**	**0**	**0**	**0**	**0**	**0**	**0.1 (0-<1)**
Braeburn														
Neaves	5 Feb	?	50	0	0	50	0	0	0	0	0	0	0	0.1
Doubleday	10 Feb	?	84	4	0	8	0	0	0	0	4	0	0	4.8
Doubleday	10 Feb	?	50	20	0	0	0	0	0	0	30	0	0	1.0
NFF	12 Feb	19 Oct	24	8	4	12	32	0	0	20	0	0	0	0.5
NFF	12 Feb	19 Oct	14	56	3	21	3	0	0	0	3	0	0	0.1
Mansfield	12 Feb	21 Oct	6	31	14	23	20	6	0	0	0	0	0	<0.5
Neaves	12 Feb	22 Oct	100	0	0	0	0	0	0	0	0	0	0	<0.1
Mansfield	26 Feb	?	0	0	0	0	0	0	0	0	0	0	0	0
Mean			**41.0**	**14.9**	**2.6**	**14.3**	**6.9**	**0.8**	**0**	**2.5**	**4.6**	**0**	**0**	**0.9 (0-4.8)**

Table 7. Losses due to rots and rot incidence in apples cvs Gala and Egremont Russet assessed during grading at various packhouses in Kent in January-March 2009

Packhouse	Date assessed	Date picked	Brown rot	Botrytis	Phytophthora	Penicillium	Nectria	Gloeosporium	Colletotrichum	Fusarium	Mucor	Botryosphaeria	Phomopsis	% Loss estimated
Gala														
Neaves	5 Feb	?	33	29	12	4	22	0	0	0	0	0	0	1.0
Amsbury	11 Feb	1 Oct	46.2	7.7	0	5.4	28.1	0	0	5.0	7.7	0	0	<0.5
Mansfield	19 Feb	24 Sep	0	0	0	0	0	0	0	0	0	0	0	neg
Mansfield	26 Feb	?	14	14	7	7	54	0	0	4	0	0	0	0.5
Mansfield	5 Mar	?	9	0	82	0	9	0	0	0	0	0	0	<0.5
Mean			**20.4**	**10.1**	**20.2**	**3.3**	**22.6**	**0**	**0**	**1.8**	**1.5**	**0**	**0**	**<0.5 (<0.5-1)**
Egremont Russet														
The Breach	11 Feb	?	51	5	0	18	19	7	0	0	0	0	0	1.5
The Breach	18 Feb	?	8	2	0	15	44	31	0	0	0	0	0	2.0
River Farm	18 Feb	?	83	2	0	8	4	0	0	3	0	0	0	1.0
Mean			**47.3**	**3.0**	**0**	**13.7**	**22.3**	**12.7**	**0**	**1.0**	**0**	**0**	**0**	**1.5 (1-2)**

Table 8. Losses due to rots and % rot incidence in apples cv. Bramley's Seedling assessed during grading at various packhouses in Kent and Herefordshire in January-March 2009

Packhouse	Date assessed	Date picked	Brown rot	Botrytis	Phytophthora	Penicillium	Nectria	Gloeosporium	Colletotrichum	Fusarium	Mucor	Botryosphaeria	Phomopsis	Other	% Loss estimated
The Breach	22 Jan	?	43	4	2	24	15	0	0	6	1	1	3	1	<1
The Breach	28 Jan	?	29	1	10	28	16	0	4	10	1	0	1	0	1.0
Jan mean			**36.0**	**2.5**	**6.0**	**26.0**	**15.5**	**0**	**2.0**	**8.0**	**1.0**	**0.5**	**2.0**	**0.5**	**0.8**
The Breach	4 Feb	17 Sep	86	4	0	2	2	0	0	2	0	0	4	0	4.0
Mansfield	5 Feb	?	36	12	3	2	12	0	0	31	2	0	2	0	1.5
Amsbury	11 Feb	?	77	0	0	5	7	0	0	4	2	0	5	0	<1
The Breach	11 Feb	27 Aug	28	6	0	26	8	0	0	28	0	0	4	0	2.5
Chambers	11 Feb	?	14	4	0	27	32	0	0	13	0	0	10	0	<1
Chambers	18 Feb	?	50	1	1	17	14	0	1	12	0	0	4	0	1.0
The Breach	18 Feb	?	39	3	0	5	15	0	0	5	0	0	33	0	1.5
Mansfield	19 Feb	?	67	1	0	9	5	0	0	7	0	0	11	0	2.0
NFF	5 Mar	15 Sep	51	0	2	6	19	0	0	18	0	2	2	0	3.0
Feb/March Mean			**49.8**	**3.4**	**0.7**	**11.0**	**12.7**	**0**	**0.1**	**13.3**	**0.4**	**0.2**	**8.3**	**0**	**1.8**
Overall mean			**42.3**	**3.3**	**1.6**	**13.7**	**13.2**	**0**	**0.5**	**12.4**	**0.5**	**0.3**	**7.2**	**0.1**	**1.6**
Wye Fruit	24 Feb	?	8	0	0	1	12	0	49	30	0	0	0	0	?

Table 9. Losses due to rots and % rot incidence in pears cvs Conference and Comice assessed during grading at various packhouses in Kent in January-March 2009

Packhouse	Date assessed	Date Picked	Brown rot	Botrytis	Phytophthora	Penicillium	Nectria	Gloeosporium	Alternaria	Fusarium	Mucor	Potebniamyces	Phomopsis	Other	% Loss estimated
Conference															
Amsbury	22 Jan	?	80	2.9	0	0	8.6	0	8.6	0	0	0	0	0	0.5
River Farm	11 Feb	29 Aug	51	21	0	15	0	0	0	0	3	10	0	0	0.5
Mansfield	12 Feb	8 Sep	28	50	0	8	4	0	4	0	2	4	0	0	0.5
NFF	19 Feb	?	25	56	0	6	8	3	0	0	0	2	0	0	2.5
NFF	26 Feb	?	31	36	0	11	16	0	0	0	4	2	0	0	1.0
Mansfield	5 Mar	?	59	22	0	7	3	2	3	0	4	0	0	0	2.5
Mean			**45.7**	**31.3**	**0**	**7.8**	**6.6**	**0.8**	**2.6**	**0**	**2.2**	**3.0**	**0**	**0**	**1.3**
Comice															
Amsbury	22 Jan	?	8	83	0	3	3	3	0	0	0	0	0	0	1.0
Amsbury	28 Jan	20 Sep	19	75	0	1	4	0	0	0	1	0	0	0	1.5
Amsbury	4 Feb	?	20	73	0	3	0	0	0	0	0	4	0	0	1.0
NFF	5 Feb	?	6	77	0	4	3	2	0	3	2	0	0	3	2.5
Mean			**13.3**	**77.0**	**0**	**2.8**	**2.5**	**1.3**	**0**	**0.8**	**0.8**	**1.0**	**0**	**0.8**	**1.5**

Control of storage rots

<u>Treatments</u>

The dates treatments were applied are shown in Table 10. Treatments were all applied on the same day.

<u>Orchard rots</u>

The incidence of *n*ectria eye rot in the orchard was very low and not recorded.

<u>Assessment of rots</u>

Fruit was harvested on 10 September 2009 and stored until March 2010. The rots present in each bin were assessed separately. The bin was first weighed and then tipped on to a sorting table and the rots removed identified and the number and weight of each rot type present recorded. Rot incidence was expressed as percentage rots by weight for each bin.

In general, the incidence of storage rots was low with just over 2% rotting in total in untreated plots (Table 12). Overall there was significantly more rotting in untreated plots compared to treated plots (p=0.021). Treatments 3 and 4 had significantly less rots in total than the untreated. The main rots recorded were brown rot, *b*otrytis, *p*enicillium, *n*ectria, *p*homopsis, *b*otryosphaeria and colletotrichum. In general most rotting was recorded in the untreated plots apart from *p*enicillium. Overall significantly less rotting was recorded in treated plots compared to untreated plots for *n*ectria (p=0.064), *p*homopsis (p=0.026) and *b*otryosphaeria (p=0.017). There were no significant effects of treatments on brown rot, *b*otrytis, *p*enicillium or *c*olletotrichum. For *n*ectria the lowest incidence of rotting was in treatments 2 and 4 in which sprays had been applied in late blossom and petal fall. However the incidence of *n*ectria rot (0.14% in untreated plots) was really too low for the results to be meaningful.

Recent work has shown that nectria infection of fruit mainly occurs during late blossom and petal fall (Xu & Robinson, 2010). Rain fall during this period was low and not favourable for fruit infection (Table 11 and appendix). Hence insufficient rotting was recorded after storage for meaningful conclusions to be drawn. There was confusion over the early season treatments such that a mixture of Captan + Bellis was applied in late blossom and petal fall rather than the individual treatments with each product as planned. However, the incidence of rotting was so low due to the low rainfall at critical periods this error in treatment has not really affected the outcome of the trial. Correct treatments will be applied in 2010.

Table 10. Treatment application dates in 2009

Growth stage and planned spray schedule	Spray application date
Late bloom	27 April
10 days later	7 May
28 days pre-harvest	3 August
14 days pre-harvest	24 August

Table 11. Rainfall and rain days recorded before and after the treatment periods in 2009

Treatment timing/spray date	Rainfall (mm) in 14 days before treatment	No. of rain days in 14 days before treatment	Rainfall (mm) in 14 days after treatment	No. of rain days in 14 days after treatment
27 April	22.8	7	8.6	4
7 May	12.0	5	13.6	6
3 August	32.8	11	12.4	4
24 August	8.4	4	10.2	7

Table 12. Mean % losses (angular transformed) due to various rots in Cox apples in orchard TL109 following treatment with various fungicide programmes applied at blossom and/or pre-harvest in 2009. Fruit was stored at 3.5°C in controlled atmosphere conditions for six months. Figures in brackets are back transformed means data

Treatment	Brown rot	Botrytis	Penicillium	Nectria	Phomopsis	Botryosphaeria	Colletotrichum	Total rots
1 Untreated	5.6 (0.9)	2.2 (0.15)	0.6 (0.01)	2.2 (0.14)	3.4 (0.36)	2.4 (0.17)	3.5 (0.36)	8.5 (2.2)
2 Captan/Bellis blossom only	6.0 (1.1)	1.7 (0.09)	0.9 (0.02)	0.5 (0.01)	1.1 (0.04)	1.2 (0.04)	1.8 (0.1)	7.7 (1.8)
3 Captan/Bellis pre-harvest only	4.8 (0.7)	1.4 (0.06)	1.2 (0.04)	1.1 (0.04)	1.6 (0.07)	1.5 (0.07)	1.3 (0.06)	**6.2 (1.2)**
4 Captan/Bellis blossom + pre-harvest	4.8 (0.7)	2.2 (0.15)	0	0.8 (0.02)	1.5 (0.07)	0	0.8 (0.02)	**5.7 (1.0)**
5 Captan/Bellis blossom only selective picking at harvest	5.6 (1.0)	0.9 (0.03)	0.5 (0.01)	1.2 (0.04)	2.3 (0.17)	1.0 (0.03)	2.7 (0.23)	7.4 (1.7)
F Prob	0.387	0.660	0.245	0.826	0.546	0.158	0.592	0.082
SED (8)	0.819	1.040	0.557	0.756	0.840	0.603	1.411	0.751
LSD (P=0.05)	1.890	2.398	1.284	1.743	1.937	1.391	3.255	1.732

Conclusions

Rot survey

- Actual losses in Cox and Gala due to rots were very low, less than 2% losses overall, range <0.5-5%
- Most losses were due to brown rot (*Monilinia fructigena*) which accounted for over a third of losses. Nectria accounted for about 20% of losses with *b*otrytis and *g*loeosporium also important
- Phytophthora, *c*olletotrichum, *f*usarium, *b*otryosphaeria, *p*homopsis and *m*ucor were also recorded at low incidence
- In Braeburn and Jazz, harvested in October, losses due to rots were negligible. On average most losses were due to brown rot. Phytophthora, *b*otrytis, *p*enicillium, *n*ectria, *g*loeosporium, *f*usarium and *m*ucor were also recorded
- In Bramley losses due to rots were on average 1.8% (range <1-4%). As with the other cultivars, on average, most of the losses (over 40%) were accounted for by brown rot. Botrytis, *p*enicillium, *n*ectria, *f*usarium and *p*homopsis were also present
- Much of the *f*usarium was present as cheek rots which appeared to have originated from the core
- Losses due to rots in Conference and Comice were on average 1.3% (range 0.5-2.5%). Over three quarters of this rotting was accounted for by *b*otrytis and brown rot. The incidence of other rots was very low

Control of storage rots

- The incidence of storage rots was low with just over 2% rotting in total in untreated plots
- Overall there was significantly more rotting in untreated plots compared to treated plots

- Treatments 3 and 4 had significantly less rots in total than the untreated
- The main rots recorded were brown rot, Botrytis, *p*enicillium, *n*ectria, *p*homopsis, *b*otryosphaeria and *c*olletotrichum
- In general most rotting was recorded in the untreated plots apart from *p*enicillium
- Overall significantly less rotting was recorded in treated plots compared to untreated plots for *n*ectria, *p*homopsis and *b*otryosphaeria but the incidence of rots was too low for differences between individual treatments to be identified
- There were no significant effects of treatments on brown rot, *b*otrytis, *p*enicillium or *c*olletotrichum

Technology transfer

The results of the rot survey were reported at the EMRA/Marden Fruit Show Society Storage Day in March 2010.

References

Berrie, A.M. (1997). Progress towards integrated control of storage rots of Cox apples. *IOBC/WPRS Bulletin*, 20, (9), 23-31

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Acknowledgements

The assistance of farm and trials staff at East Malling Research, especially Karen Lower and Tom Passey, with the trial is greatly appreciated.

APPENDIX

Weather data for East Malling (1 March – 30 September 2009)

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
01/03/2009	9.4	1	0.2
02/03/2009	10.9	5.7	0
03/03/2009	9	3.9	14.2
04/03/2009	7.2	-1.3	1.2
05/03/2009	8	-0.6	0.2
06/03/2009	10.2	0.7	0
07/03/2009	12.1	5.9	0.4
08/03/2009	10.5	1.7	2.6
09/03/2009	10.5	6.2	6.2
10/03/2009	12.5	-0.2	2
11/03/2009	12	6.1	0
12/03/2009	12.9	3.9	0
13/03/2009	11.4	6	0
14/03/2009	13.2	2.6	0
15/03/2009	14.3	1.5	0
16/03/2009	15	1.5	0.2
17/03/2009	12.8	0.4	0
18/03/2009	15.3	-0.5	0.2
19/03/2009	9.9	-0.2	0
20/03/2009	11.4	-3.4	0
21/03/2009	14.7	5.6	0
22/03/2009	14.8	5.8	0
23/03/2009	13.3	2.3	3.4
24/03/2009	10.9	5.7	1.6
25/03/2009	11.7	6.8	2
26/03/2009	13.1	3.9	2.8
27/03/2009	10.4	1.1	0.8
28/03/2009	9.1	0.4	3.2
29/03/2009	9.6	-1.7	0
30/03/2009	13.3	6.3	0
31/03/2009	14.3	2.4	0
01/04/2009	13.5	7	0
02/04/2009	13.9	5	0
03/04/2009	12.3	5.4	0
04/04/2009	17.1	2.7	0
05/04/2009	15.3	6.8	0
06/04/2009	17.3	8	0
07/04/2009	14.5	7.3	2.2
08/04/2009	15.9	4.6	0.2
09/04/2009	15.3	8.3	0
10/04/2009	17	9.8	2.6
11/04/2009	14.8	9.8	1
12/04/2009	14.2	10.8	0.2
13/04/2009	16.4	5.3	0
14/04/2009	17.1	9.2	3.2
15/04/2009	22.1	10.7	0.4
16/04/2009	15	8.4	9.2
17/04/2009	10.4	6	5.2
18/04/2009	13.3	4.8	0

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
19/04/2009	14.7	7.4	0
20/04/2009	17.5	2.2	0.2
21/04/2009	19.8	6.7	0
22/04/2009	19	4.4	0
23/04/2009	17.3	8.1	0
24/04/2009	17	10.1	0
25/04/2009	14.6	1.6	0
26/04/2009	17.3	4.5	0.2
27/04/2009	11.1	1.5	4.4
28/04/2009	12.8	1.4	6
29/04/2009	16.6	4.3	0
30/04/2009	17.5	5.5	0
01/05/2009	19.7	8.9	0
02/05/2009	18.6	8.3	0.2
03/05/2009	15.3	3.1	0
04/05/2009	14.5	10.5	0
05/05/2009	19.3	10.9	0
06/05/2009	20	8	0
07/05/2009	14.8	7.9	1.2
08/05/2009	15.9	4.2	1.2
09/05/2009	17	4	0
10/05/2009	17.7	9.4	0
11/05/2009	12.8	8.8	0
12/05/2009	14.2	11.1	0.2
13/05/2009	14.9	10.7	0
14/05/2009	17.8	11.4	2.2
15/05/2009	15.4	6.7	2.2
16/05/2009	16.2	8.1	0
17/05/2009	15.3	9	4.6
18/05/2009	15.7	8.8	3.2
19/05/2009	16.9	6.1	0
20/05/2009	18.6	6.9	0
21/05/2009	19.2	5.5	0
22/05/2009	18.5	5.7	0
23/05/2009	19.3	6	0.2
24/05/2009	21.1	9	0
25/05/2009	23.6	11	8
26/05/2009	17.2	7.2	0.2
27/05/2009	17.3	11.2	0.6
28/05/2009	22.3	10.3	0.2
29/05/2009	22	10	0
30/05/2009	20.5	11	0
31/05/2009	21.6	11.9	0
01/06/2009	22.9	11	0
02/06/2009	23.4	9.6	0
03/06/2009	16.8	5.3	0
04/06/2009	16.8	7	0
05/06/2009	13.3	9.6	0.4
06/06/2009	14.9	8.8	7.2
07/06/2009	17.1	5.3	0.2
08/06/2009	16.7	10.4	14.4
09/06/2009	16.2	9.2	2.2
10/06/2009	17.7	8.6	2.2

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
11/06/2009	19.7	5.7	0
12/06/2009	19.6	12.4	0
13/06/2009	22.3	13.7	0
14/06/2009	23.8	13.7	0
15/06/2009	21.9	11	0
16/06/2009	21.6	8.1	0
17/06/2009	22.1	10.3	0
18/06/2009	18.9	10.2	0
19/06/2009	19.3	10.8	0
20/06/2009	18.9	11.9	0.2
21/06/2009	21.2	8.4	0
22/06/2009	21.1	12.3	0
23/06/2009	21.2	12.9	0
24/06/2009	21.1	14.3	0
25/06/2009	23.4	15.4	0
26/06/2009	24.2	15.8	0
27/06/2009	26	11.3	0.4
28/06/2009	25.9	12.5	0
29/06/2009	29	13.3	0
30/06/2009	27	14	0
01/07/2009	25.3	12.9	0
02/07/2009	27.6	18.1	1.6
03/07/2009	25.1	12.5	0
04/07/2009	25.3	15.6	0.8
05/07/2009	23.6	12.6	1
06/07/2009	20	13.8	4.4
07/07/2009	21.1	12.1	13.4
08/07/2009	20	11.9	1.4
09/07/2009	19.5	10.5	0
10/07/2009	21.3	14	0
11/07/2009	19.1	14.7	3.8
12/07/2009	22.5	10.7	0
13/07/2009	22.6	14.1	0
14/07/2009	22.9	14	1
15/07/2009	21	11.9	0.4
16/07/2009	23.7	15.1	3
17/07/2009	19.9	13.6	1
18/07/2009	21.4	10.6	0
19/07/2009	20.4	12.2	0.2
20/07/2009	20.8	14.7	0
21/07/2009	24.6	14.7	1
22/07/2009	21.7	13	0.2
23/07/2009	22.2	13.3	2.6
24/07/2009	19.1	11.2	7.4
25/07/2009	23.1	10.8	0.2
26/07/2009	22.1	12.8	4.4
27/07/2009	20.2	11	1.2
28/07/2009	20.6	12.6	0.4
29/07/2009	21.9	11.7	7.4
30/07/2009	19.9	10.1	3.2
31/07/2009	21.1	15.3	0
01/08/2009	21.5	12.5	4.8
02/08/2009	21.8	9.4	0

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
03/08/2009	21.8	14.6	0
04/08/2009	23.1	13.5	0
05/08/2009	27.7	14.6	0
06/08/2009	29.2	16.7	6.4
07/08/2009	21.4	10.9	0.2
08/08/2009	24.4	12.1	0
09/08/2009	23.8	11.6	0
10/08/2009	22.7	17.1	0
11/08/2009	25.2	14.6	0
12/08/2009	23.8	15.1	5.6
13/08/2009	23.5	12.6	0
14/08/2009	21.4	13.4	0
15/08/2009	22.9	14.5	0.2
16/08/2009	24.7	12.3	0
17/08/2009	23.3	11.1	0
18/08/2009	24.2	10.7	0
19/08/2009	28.8	13.3	0
20/08/2009	23.7	11.7	0
21/08/2009	21.5	8.7	2.4
22/08/2009	22.7	12.1	0.2
23/08/2009	26.8	11	0
24/08/2009	24.6	9.3	0
25/08/2009	21.3	12.4	0.4
26/08/2009	22.7	16.1	0.2
27/08/2009	22	11.4	0.2
28/08/2009	20.2	10.1	0
29/08/2009	20.7	8.8	0
30/08/2009	20.8	16.3	0.2
31/08/2009	25.5	12.4	0
01/09/2009	20.3	12.9	0.2
02/09/2009	18.8	13.3	8.6
03/09/2009	18.3	9.9	0.4
04/09/2009	19.1	9.4	0
05/09/2009	20	12.8	0
06/09/2009	20.1	11.3	0
07/09/2009	24.4	15.4	0
08/09/2009	27.4	14.7	0
09/09/2009	20.7	10.8	0
10/09/2009	20.2	11.8	0
11/09/2009	20.3	13.3	0
12/09/2009	20.5	6.7	0
13/09/2009	17.9	12.9	0
14/09/2009	19.6	13.8	5.4
15/09/2009	16.3	14.2	11
16/09/2009	18.8	12.8	0
17/09/2009	17.7	8.7	0
18/09/2009	18.9	12	0
19/09/2009	22.4	12.9	0
20/09/2009	19.6	11	0
21/09/2009	21.4	11	0
22/09/2009	21.6	15.2	0
23/09/2009	20	8.6	0.2
24/09/2009	20	6.6	0.2

WEATHER_DATE	TEMP_MAX	TEMP_MIN	RAINFALL
25/09/2009	20.6	5.2	0
26/09/2009	20.5	5.7	0
27/09/2009	21	7.2	0.2
28/09/2009	18.5	9.4	0
29/09/2009	21.4	9.5	0.2
30/09/2009	18	13.5	0

