Horticultural Fellowship Awards

Interim Report Form

Project title:	Succession planning to sustain the UK's expertise in field and laboratory plant pathology research and development
Project number:	CP 090
Project leader:	Dr Angela Berrie East Malling Research
Report:	Annual report, October, 2013
Previous report:	Annual report, September, 2012
Fellowship staff: ("Trainees")	Dr Robert Saville
Location of project:	East Malling Research
Industry Representative:	Marion Regan, Hugh Lowe Farms
Date project commenced:	7 November 2011
Date project completed (or expected completion date):	6 November 2016

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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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Progress Against Objectives

Objectives

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
1. Identify and recruit a successor with the most appropriate background to act as understudy to Dr Berrie.	07/11/11	07/11/11	
2. Develop and deliver a training programme to provide the post-holder with skills and experience in the identification of field and laboratory pathology and an ability to conduct and advise on commercial disease management strategies.	06/11/16	ongoing	
3. Facilitate the development of a successor to Dr Berrie through a programme of collaboration (with other technical experts outside EMR), education, demonstration and shadowing, and industry communication to provide the successor with the skills to deliver practical disease management R&D in fruit and other perennial crops.	06/11/16	ongoing	
4. Enable the post-holder to instigate their own sources of income and the delivery of strategic and applied R&D to act as the means to sustain future innovation within commercial horticulture.	06/11/16	ongoing	

Summary of Progress

1. Identify and recruit a successor with the most appropriate background to act as understudy to Dr Berrie. **Completed**

Robert Saville commenced employment at EMR in November 2011. Robert Saville joined EMR having attained his PhD at the John Innes Centre, Norwich working on the dwarfing genes of cereals, their role in cell development and their pleiotropic effects on disease. The combination of experience working with different pathosystems and molecular techniques provide a good foundation to fulfil the subsequent objectives.

2. Develop and deliver a training programme to provide the post-holder with skills and experience in the identification of field and laboratory pathology and an ability to conduct and advise on commercial disease management strategies. **Ongoing**

Three fellowship projects were outlined at the beginning of the fellowship programme which were designed to introduce the trainee to the many aspects of field and laboratory pathology and develop his skills in phytopathology research and application in horticultural crops. The initial fellowship projects are (1) sustainable control of storage rots of apple, (2) exploring the possibility of a new pathogen, *Gnomonia fragariae*, affecting UK strawberry crops and (3) evaluation of an apple mildew management programme through monitoring compared to a routine programme. The fellowship projects are reported in the science section of this report. In consultation with the industry representative of CP90 (Marion Regan), the fellowship projects are currently under review for the next three years of the fellowship with scope to take an increased focus on soft fruit. In addition to the fellowship projects, training has been provided through assistance and management of existing research projects, general on the job training and formal training courses (see training undertaken section).

Research projects with trainee involvement during reporting period;

HDC panel projects

Apple mildew sensitivity

Blueberry dieback

Fusarium mouldy core in apple

SCEPTRE

Evaluating treatments for mildew on apple

Post-harvest treatments for botrytis in pear

Evaluating treatments for mucor/rhizopus on strawberry

Evaluating treatments and application methods for crown rot in strawberry

Evaluating treatments for raspberry cane diseases

Hort-LINK projects

Minimizing residues in strawberry

Integrated pest and disease management in blackcurrant

Integrated pest and disease management in plum and cherry

TSB

Evaluating novel biofumigation products for effectiveness against *Verticillium dahliae*.

Post-harvest management of plums and cherries to minimise waste

BBSRC

NORNEX consortium – screening ash diversity set for resistance to *Hymenoscyphus pseudoalbidus* (ash dieback)

Intereg

Vegedurable 2 –improving strawberry production through addition of *Mychorrhizae*

Chemical company trials/consultancy activities

Chemical trials

Crop walking for two large top fruit farms

Shadowing Angela Berrie on ad hoc consultancy

EMR plant clinic

3. Facilitate the development of a successor to Dr Berrie through a programme of collaboration (with other technical experts outside EMR), education, demonstration and shadowing, and industry communication to provide the successor with the skills to deliver practical disease management R&D in fruit and other perennial crops. **Ongoing.**

Attendance at industry and scientific events and conferences has enabled continued personal and professional development, exposed the trainee to key industry and scientific figures and provided opportunities for future collaboration.

Interactions with industry

HDC Agronomists' day, presented "My Horticultural Fellowship"

Innovation in Horticulture Conference, presented a short biography

EMRA/HDC storage day, presented “Storage Rot Survey Update”

Norwegian fruit farmers group – a walk and talk about the TSB biofumigation project

Attendance at East Kent Fruit Society blossom walk, River Farm, Staplehurst

Attendance at Fruit Focus, East Malling

Visit to H&H Duncalfe hosted by Harriet Duncalfe, APS salads hosted by Phillip Pearson and a visit to Plumpton College wine department.

Scientific Meetings

Attendance at the British Society of Plant Pathologists (BSPP) presidential meeting, Norwich.

Attendance and presentation at the International Congress of Plant Pathologists, Beijing. Presented a paper entitled “Sustainable control of post-harvest apple rots from orchard to store”

Attendance and presentation at the Association of Applied Biologists Biocontrol and Biopesticides conference, Grantham. Presented a paper entitled “Minimising Pesticide Residues in Strawberry through integrated pest, disease and environmental crop management”

Attendance and contribution at project meetings including SCEPTRE disease group, Intereg Vegedurable 2, NORNEX kick off meeting, EU COST action on Cherry and HDC dieback workshop.

4. <u>Enable the post-holder to instigate their own sources of income and the delivery of strategic and applied R&D to act as the means to sustain future innovation within commercial horticulture.</u> **Ongoing**

Applied for BBSRC funding within NORNEX consortium to work on ash dieback disease (successful)

Applied for Worshipful Company of Fruiterers funding to work on the development of a metagenomics assay to determine the species present in environmental samples (successful)

Applied for HDC Soft Fruit Panel funding to develop integrated control of *Verticillium* wilt disease in strawberry (unsuccessful)

Applied for HDC Tree Fruit Panel funding to continue work on *Fusarium* infection of apple (pending)

Also assisted in the conception and writing of other funding bids from various sources including TSB

Milestones not being reached

All milestones are being reached.

Do remaining milestones look realistic?

All milestones have a realistic completion date.

Other achievements in the last year not originally in the objectives

Invited to speak at the Integrated Pest and Disease Management conference organised by the Nordic Association of Agricultural Scientists, Copenhagen

Appeared on BBC TV South East News to talk about ash dieback

Sat on the organising committee and chaired a session for an international conference entitled “Fruits and Roots – A Celebration and Look Forward” to be held at East Malling in November, 2013.

Co-organiser of the EMR seminar series

Institute pesticide officer

Changes to Project

Are the current objectives still appropriate for the Fellowship?

Yes

Grower Summary

The nature of the fellowship projects means that a grower summary is not appropriate at this stage.

SCIENCE SECTION

Introduction

General Background

Dr Angela Berrie has attained recognition for her role as the UK's leading field plant pathologist for fruit. With over 35 years' experience Dr Berrie's vast knowledge of plant pathology is respected by scientists and industry alike. Dr Berrie has greatly contributed to crop protection in the horticultural industry from applied field consultancy and plant clinic diagnostic skills to strategic research and development projects. A future gap in the application of these skills to UK horticulture has been identified as Dr Berrie approaches retirement. This fellowship has been created as part of the successional planning to sustain the UK's expertise in field and laboratory plant pathology research and development.

Objectives

As part of the training fellowship three projects were initially proposed to encompass some of the training requirements required for field and laboratory plant pathology research and development:

(1) Sustainable control of storage rots of apple

(2) Exploring the possibility of a new pathogen, *Gnomonia fragariae*, affecting UK strawberry plantations

(3) Assessing the effectiveness of responsive apple mildew management through monitoring compared to a routine programme.

In addition to the fellowship projects above time has been invested in assisting with existing projects at EMR and training in field and laboratory diagnostics.

Background

Sustainable control of storage rots of apple

Types of storage rot

Fungal rots can result in significant losses in stored apples, particularly in fruit stored beyond January. Certain pack houses will record losses due to rots for individual bins of fruit, thus relating the loss to particular orchards, harvest time and pre-harvest factors, however they rarely identify the rots present. It is important to identify the rot profile in stored apples over time to build a dataset (including orchards, harvest time and pre harvest factors) from which to base management strategies. In previous surveys *Nectria*, *Botrytis*, brown rot (*Monillinia*), *Penicillium*, *Phytophthora* and *Gloeosporium* have been identified as the main rots in apple. Other rots, such as *Colletotrichum sp, Fusarium sp, Botryosphaeria* and *Phomopsis,* have been increasing in incidence. A greater understanding of the epidemiology of these rots has helped in informing management strategies to reduce their prevalence.

For example, *Nectria galligena*, the causative agent of apple canker, is also responsible for causing three distinct storage rot phenotypes; stalk, eye and cheek rot. Epidemiological studies have shown that fruit is most susceptible to *N. galligena* at blossom and petal fall (Xu & Robinson, 2010) and infection invariably leads to stalk and eye rot. Fruit susceptibility was shown to decline through summer and increase slightly near harvest with infected fruit generally expressing *Nectria* cheek rot in store. In a Defra project (HH3232STF) it was shown that early season treatments targeted at *N. galligena* reduced the incidence of *Nectria* eye and stalk end rots in store. Late season treatments will reduce the incidence of *Nectria* cheek rot, however issues of residues on fruit arising from treating close to harvest mean that early marketing of fruit, particularly in orchards with high levels of canker, is advisable.

Rot risk assessment

The concept of rot risk assessment was introduced via the Apple Best Practice Guide in 2001. The rot risk assessment takes account of various pre-harvest factors to predict the level of rot likely to occur in store and thus inform a management strategy, be it pre-harvest treatments, selective picking or storage term, to minimise losses in store. The factors assessed pre-harvest are; daily rainfall, orchard factors, fungal inoculum (particularly brown rot and canker), crop load, % bare ground (*Phytophthora*), % crop <0.5 metre from the ground, orchard rot history and fruit storage potential (mineral composition and firmness). For example *Phytophthora* rot risk is influenced by three key factors; Rainfall in the 15 days prior to harvest, % bare ground and % crop <0.5 metre from ground (Table 1).

Table 1. Factors influencing the risk of *Phytophthora* rot

Factor	Criteria for risk
(1) Rainfall in 15 days prior to harvest	low or no rain = low risk 20 mm or >= high risk
(2) % bare ground	100% bare ground (overall herbicide) = high risk Overall grass or mulch or weed cover (0% bare ground) = low risk
(3) % crop <0.5 metre from ground	15% or >= risk

In addition to rot risk assessment other management strategies can be employed to minimise losses in store, such as selective picking. Only undamaged fruit is harvested and all fruit below 0.5 metres above the ground is excluded. This reduces the risk of introducing fungal rots, such as brown rot and *Penicillium* rot which establish on damaged fruit, and also *Phytophthora* rot which is prevalent on low hanging fruit, into the bin.

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. By applying the recommendations set out in the rot risk assessment as part of an IPM approach such treatments could be avoided, thus reducing the risk of pesticide residues on fruit whilst reducing the financial and environmental costs of pesticide application.

In previous rot surveys a trend has emerged of an increasing prevalence of *Gloeosporium* rot. Current research has not identified any clear factors on which risk assessment could be based apart from fruit set (light crop = risk). Decisions on risk are therefore mainly based on rot history and rainfall. As the trend of increasing losses due to *Gloeosporium* is likely to continue, it is important to continue to monitor the prevalence of this storage rot to increase our understanding of rot occurrence and develop preventative measures to reduce rot incidence.

Exploring the possibility of a new pathogen, Gnomonia fragariae*, affecting UK strawberry plantations*

Strawberry plays host to a large number of pathogens which can weaken and kill infected plants, resulting in a reduction in a plantations fruit yield and quality. Among these pathogens is a group which causes disease in the root system, crown and base of petioles. These diseases can cause serious damage to the host due to the disruption of the vascular system supplying the rest of the plant with water and nutrients, and can be costly to growers due to the increased cost associated with gapping-up dead plants or prematurely grubbing the plantation. Such diseases include crown rot and red stele caused by *Phytophthora cactorum* and *P. fragariae* respectively, *Verticillium* wilt and disorders caused by *Colletotrichum* species.

It is these diseases which have contributed to the large scale adoption of the production systems used in modern strawberry production, whereby plantations are replanted on a yearly or two-yearly cycle rather than being a ‘multi-year’ perennial crop. The emergence of new pathogen threats is increasing with an increase in worldwide trade of produce and nursery stock and with the changing climate. It is important to identify these threats early so that diagnostics and control measures can be improved and implemented more rapidly. It is on this basis that investigations have been implemented on the presence of a new pathogen, *Gnomonia fragariae*, in UK strawberry plantations.

Gnomonia fragariae is an *Ascomycete* fungus belonging to the genus *Diaporthales*. *G. fragariae* has long been considered as a saprophyte colonising dead tissues of strawberry plants (Klebahn, 1918). However it has recently been shown to be the cause of a severe root rot and petiole blight of strawberry in Latvia and Sweden (Morocko *et al.* 2006). The disease causes a black rot on petiole bases, discolouration of rhizome tissues and crown, collapse of plants from one side, red or yellow coloured older leaves and bluish green colour of younger leaves. Most of these symptoms are indicative of *Phytophthora* infection and therefore may have been misidentified as such in the past. In fact anecdotal evidence suggests that UK derived samples that show all the hallmarks of crown rot infection have failed to be confirmed using standard traditional procedures (EMR Plant clinic samples, Dr Angela Berrie, pers. comm.). The diagnosis, and therefore detection of the presence of *G. fragariae* in UK strawberries, is further hindered by the slow growth of fungus in culture, meaning that colonies are often overgrown by faster-growing fungi.

Apple powdery mildew (Podosphaera leucotricha) is a major pathogen affecting apple production. The disease can severely reduce yield and quality (through russeting and cracking) particularly on susceptible varieties such as Cox and Jonagold. Some varieties, such as Golden Delicious, have increased tolerance to mildew epidemics, meaning that the disease is less detrimental to yield and quality. Breeding of varieties with increased resistance and tolerance is possible and such varieties are utilised in organic production systems. However, market forces dictate that susceptible varieties are still grown in conventional systems, meaning that growers are heavily reliant on chemical control to manage mildew epidemics.

An investigation of the extent of *G. fragariae* is required in the UK and robust and reliable diagnostic procedures developed in order to provide advice on effective control measures to minimise its detrimental effect on UK strawberry production. EMR staff are well placed to carry out such investigations as the plant clinic service receives ~200 samples per year for diagnosis and testing. Among these we can assess the level of *G. fragariae* in the field. EMR also hosts scientists with a lot of experience in diagnostics and field isolation of pathogens. A field survey will also be conducted once suitable sites have been identified.

Assessing the effectiveness of responsive apple mildew management through monitoring compared to a routine programme

The lifecycle of any disease is important to consider when developing effective management strategies, particularly on a perennial crop such as apple. *P. leucotricha* over-winters as mycelium in the fruit and vegetative buds formed in the previous season, therefore the level of disease at the end of the previous season will influence the epidemic in the following season. These buds emerge in spring, either as mildewed blossoms at pink bud or mildewed shoot tips at petal fall, known as primary mildew. The inoculum from the primary mildew spreads to extending shoots to create a secondary mildew epidemic which, under favourable conditions, can infect leaves and produce sporulating mildew colonies in about 4-5 days. If the secondary mildew epidemic is high, fruit and vegetative buds are colonised as they develop and seal and the fungus remains quiescent on the dormant buds until the following spring. Season-long chemical treatment, preferably with alternating chemistry to avoid fungicide resistance, is therefore required to evade a mildew epidemic.

The key factor for effective control of a mildew epidemic in apple is to maintain primary mildew at a low level. This can be achieved throughout the season. Physical removal of mildewed blossoms and shoots may be necessary at the beginning of the season where mildew levels are high. Keeping on top of the secondary mildew epidemic will reduce the following season's primary mildew epidemic and it is important to maintain chemical control throughout the season right from green cluster until vegetative growth ceases. However it is also important to adopt a flexible and responsive approach to chemical control which can be achieved through disease monitoring. Monitoring is an important strategy in controlling a seasonal epidemic and potentially enables a grower to rationalise fungicide input and also alerts the grower to ineffectiveness of a particular product (either due to insufficient spray cover or the development of fungicide resistance in a local mildew population).

Advice to growers and agronomists is available on how to effectively manage mildew through monitoring (for example in the Apple Best Practice Guide) however as mildew epidemics are so detrimental to yield and quality of fruit, growers may be apprehensive of adopting such practices. This trial is designed as a demonstration of effectiveness of implementing a managed programme, informed by monitoring compared to a routine programme, treated every 10-14 days with a varied programme of mildewicides. The management tools available are; choice of fungicide (eradicant or protectant), fungicide dose, spray interval and spray volume. The decisions are based on; mildew incidence, growth stage and current/forecasted weather.

Materials and methods

Sustainable control of storage rots of apple

Five pack houses were visited in Kent weekly from January – March 2013. A visit was also made to a pack house in June (Table 2). Rots were assessed on the grader of whatever variety was being graded at the time of the visit. Rots were identified visually and numbers recorded. Unidentified rots were cultured on to PDA and identified from spores or characteristic culture growth.

Table 2 Fruit pack houses visited weekly in January – March and June (*) 2013

Pack house	Location	Number of times visited
Newmafruit Farms Ltd	Howfield Farm, Chartham Hatch, Kent	8
F W Mansfield & Sons Ltd	Nickle Farm, Chartham, Kent	8
The Breach	Goudhurst, Kent	12*
Bardsley & Sons	River Farm, Staplehurst, Kent	10
J L Baxter & Son Ltd	Amsbury Farm, Hunton, Kent	10

Exploring the possibility of a new pathogen, Gnomonia fragariae, affecting UK strawberry plantations

Strawberry samples submitted to the EMR plant clinic which have characteristic symptoms of *G. fragariae* during 2012 and 2013 have undergone standard diagnostic tests. Samples which looked characteristic of crown rot (i.e. wilted, bluish-green young leaves, all or part of the plant dead or stunted, discoloured crowns and root rot in later stages) were tested using traditional diagnostic tests (floating crown and petiole tissue on water and assessing for the presence of sporangia following incubation at room temperature for 48hrs) and using molecular biology techniques (Lateral flow devices, Forsite Diagnostics, UK). Positives were reported as such whilst negatives were further analysed (below) for *G. fragariae*. Field samples have been collected from sites in which the disease is suspected to be present based on symptoms consistent with those described for *G. fragariae* (Fig. 1) being exhibited. In addition a fact sheet (Appendix 2) has been disseminated through the agronomist network to raise awareness of the disease, to crowd source infected material and to identify sites which could be sampled for the disease.

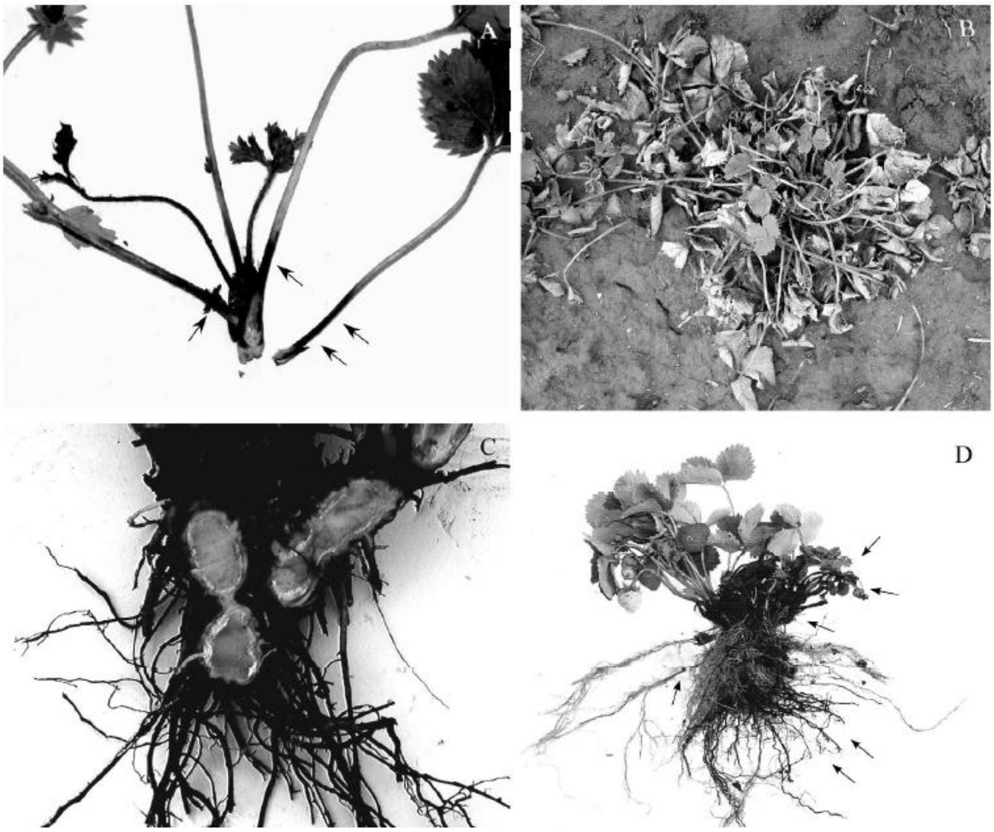

Figure. 1 Typical disease symptoms of strawberry plants infected with *G. fragariae* in the field: (A) black rot on petiole bases; (B) collapsed outer leaves; (C) black root rot and discoloration in crown; (D) severe stunt, black rot on roots and collapse of plant from one side. Figure from Morocko, 2006, Doctoral thesis.

Isolation methods have been adapted from Morocko *et al.* (2006). Briefly, stem bases, crowns and roots showing disease symptoms are surface sterilised in 1.25% sodium hypochlorite for 2-3 minutes then washed three times in sterile distilled water and dried. Tissue at the leading edge of infection (i.e. the margin of healthy and diseased tissue) is plated on water agar media. Infected material was also prepared as above for incubation in damp chambers (enclosed lunch boxes lined with damp tissue paper) to encourage the formation of fruiting bodies. Permutations on the published methodology described above; incubating infected material at 4°C for 1-3 months which has been shown to increase the success rate of isolations (Dr Inga Morocko-Bicevska, pers. comm.), inclusion of a paraquat soak when preparing plant material for isolation, supplementing agar with paraquat, using different agars and incubation under UV light.

Assessing the effectiveness of responsive apple mildew management through monitoring compared to a routine programme.

Site

Orchard EE190, Home Farm, East Malling. The orchard was planted in 1998 and consists of alternate rows of Royal Gala and Self Fertile Queen Cox. Tree spacing is 3.5m between rows and 1.75m between trees in the row. Two plots were marked out; Managed (blue) and Routine (red). Each plot consists of six rows of each cultivar with 29 trees in each row making each plot 0.19 ha in area. This is the second year that the managed and routine programmes have been implemented and assessed.

Treatments

Both plots were treated with a common scab and insecticide program throughout the growing season. The routine plot was treated with a standard mildewcide programme sticking to a 10-14 day spray interval (Table 3). The frequency, dose, volume and choice of fungicide in the managed programme were determined by monitoring (Table 3).

Table 3. Treatment programmes applied to routine and managed plots through trial period.

Treatment number	Date applied	Product	Active	Dose rate/ha	Concentration	Routine[1] (Red)	Managed[1] (Blue)
1	15/05/2013	Kindred	meptyldinocap	0.6L		Y	Y
2	29/05/2013	Systhane	myclobutanil + cyclohexanone	0.33L	1.65ml	Y	Y
3	14/06/2013	SF-2013-APL-32[2]	-	0.5L	2.5ml	Y	Y
4	26/06/2013	SF-2013-APL-128[2]	-	1.875kg	9.4g	Y	Y
5	03/07/2013	Topas	penconazole	0.5L	1ml		Y
6	15/07/2013	Cosine	cyflufenamid	0.5L	2.5ml	Y	Y
7	24/07/2013	Kumulus DF	sulphur	5kg	10g		Y
8	07/08/2013	Systhane	myclobutanil + cyclohexanone	0.33L	1.65ml	Y	Y
9	21/08/2013	Topas	penconazole	0.5L	1ml	Y	Y

[1] Y denotes treatment was applied in plot

[2] SCEPTRE coded products

Monitoring

In the managed plot only, 20 shoots were assessed weekly in June and through to July for the presence of secondary mildew by examining the top five leaves starting with the first fully expanded leaf. If mildew was present on any of the leaves the shoot was recorded as mildewed. The result is expressed as % mildewed shoots. Table 4 describes the guidelines for decisions on fungicide use in the managed programme based on secondary mildew assessments (Apple Best Practice Guide, Defra).

Table 4. Guidelines for decisions on fungicide use based on secondary mildew monitoring assessments. Adapted from the Apple Best Practice Guide, Defra

Disease rating	Mildewed shoots (%)	Action after petal fall
low	<10	In cool weather with rainy spells or when shoot growth is slow, there is an opportunity to reduce fungicide by reducing dose (minimum dose = 25%) or extending spray interval.
moderate	10-30	Maintain control. Consider improving programme by reducing spray interval or increasing fungicide dose (not exceeding label maximum) especially if weather is warm and humid and shoot growth rapid.
potentially high	>30	Improve control immediately especially if shoots are growing, irrespective of weather. Shorten spray interval, increase fungicide dose (not exceeding label maximum), possibly increase spray volume. Consider changing fungicide. Check sprayer is working correctly.

Assessments

Primary blossom mildew was assessed as the number of mildewed blossoms out of 10 blossoms on four branches of 10 trees of each cultivar assessed per plot, as described in the Apple Best Practice Guide, Defra. The result is expressed as % mildewed blossoms.

Primary vegetative mildew was assessed as total number of shoots per tree and number with mildew on ten trees per cultivar per plot, as described in the Apple Best Practice Guide, Defra. The result is expressed as % mildewed shoots.

Secondary mildew was assessed as numbers of mildewed leaves of top five leaves per shoot, taking first fully unfurled leaf as leaf 1. Five shoots on 20 trees were assessed per cultivar per plot. Secondary mildew was assessed in June and July.

Monthly rainfall data collected at East Malling through the 2012 growing season is displayed in Table 5 in relation to the 50 year average. Rainfall greatly exceeded the 50 year average for April, June, July and October. Increased rainfall during these periods is significant for rot development in store because they coincide with periods of susceptibility to certain rots i.e flowering and early fruit set (e.g. latent infections of Nectria, Fusarium and Botrytis) and harvest (e.g. Phytophthora).

Table 5. Monthly rainfall (mm) recorded at East Malling from March to October 2012. 50 year average rainfall is presented for comparison.

Month	2012	50 year average
March	21.8	44.3
April	113.4	44.5
May	56.8	45.8
June	107.8	49.7
July	102.4	46.4
August	39.2	52
September	61.2	63.7
October	133.4	65.6

Results

A total of 75 samples were surveyed in the 2012/13 rot survey (Table 6 and Appendix 1) representing 15 different cultivars. The greatest numbers of samples were of Cox, Gala and Bramley, reflecting the dominance of these varieties in the UK. The conditions conducive to fruit infection (high rainfall during susceptible periods) experienced during the 2012 growing season is evident from the rot survey with an overall mean loss of 2.6%, a commercially significant loss, compared to 1.4% mean loss the previous season. An increase in the overall average is mainly a result of increases in losses recorded in Gala (+2% compared to 2011), Jazz (+1.4%) and Rubens (+1.6%) which were mostly attributed to an increase of *Nectria*. Losses by cultivar are summarised for selected cultivars for 2012 and the previous four growing seasons in Figure 2. It is evident from this data set that losses were generally higher in all cultivars and in particular cultivars which usually only suffer minimal losses (e.g. Gala and Jazz).

Table 6. Summary table of rot survey data collected during the 2012/13 storage season. The table shows the average percentage loss attributed to each rot for each cultivar recorded during the survey together with the number of samples recorded for each cultivar and the average percentage loss. Raw data presented in appendix 1.

Cultivar	Average % of loss attributed to each rot;														Number of samples	Loss (%)
	Brown rot	*Botyrtis*	*Phytopthora*	*Penicillium*	*Nectria*	*Gleosporium*	*Fusarium*	*Mucor*	*Botryosphiria*	*Phomopsis*	Stalk	Eye	Cheek	Core		
Braeburn	28.0	7.4	9.2	5.5	31.7	8.7	4.1	2.5	0.0	0.0	1.2	0.3	0.0	1.4	9	0.3
Cox	39.1	7.6	2.3	4.7	35.7	3.2	1.9	0.3	0.2	0.1	0.0	0.0	0.0	5.1	16	4.6
Gala	28.1	11.8	1.5	6.7	33.3	3.9	0.5	1.3	0.0	0.0	2.5	0.1	1.4	8.6	14	2.4
Jazz	39.8	7.5	5.7	5.8	22.9	15.2	0.0	1.0	0.0	0.0	0.2	0.0	0.0	2.2	4	1.7
Rubens	31.8	1.9	1.0	2.0	53.5	1.4	0.0	0.0	0.0	0.0	2.6	1.0	1.6	4.2	3	1.7
Cameo	31.4	19.0	22.0	7.1	12.2	4.9	0.6	1.1	0.0	0.0	0.0	0.0	0.0	1.7	4	0.8
Egremont Russet	28.0	8.9	6.7	3.8	23.7	8.3	0.6	4.8	0.2	0.0	0.3	1.1	1.4	12.9	6	0.7
Other dessert	17.2	11.5	10.9	4.3	23.3	7.8	0.3	2.0	0.0	0.0	0.5	1.3	0.5	20.4	8	1.0
Bramley	20.6	6.6	4.2	2.0	39.8	4.8	1.1	0.4	0.1	0.0	3.9	0.6	0.1	15.8	11	5.2
Overall average	**29.1**	**9.1**	**5.7**	**4.7**	**31.9**	**5.8**	**1.3**	**1.4**	**0.1**	**0.0**	**1.4**	**0.4**	**0.5**	**8.8**	**-**	**2.6**

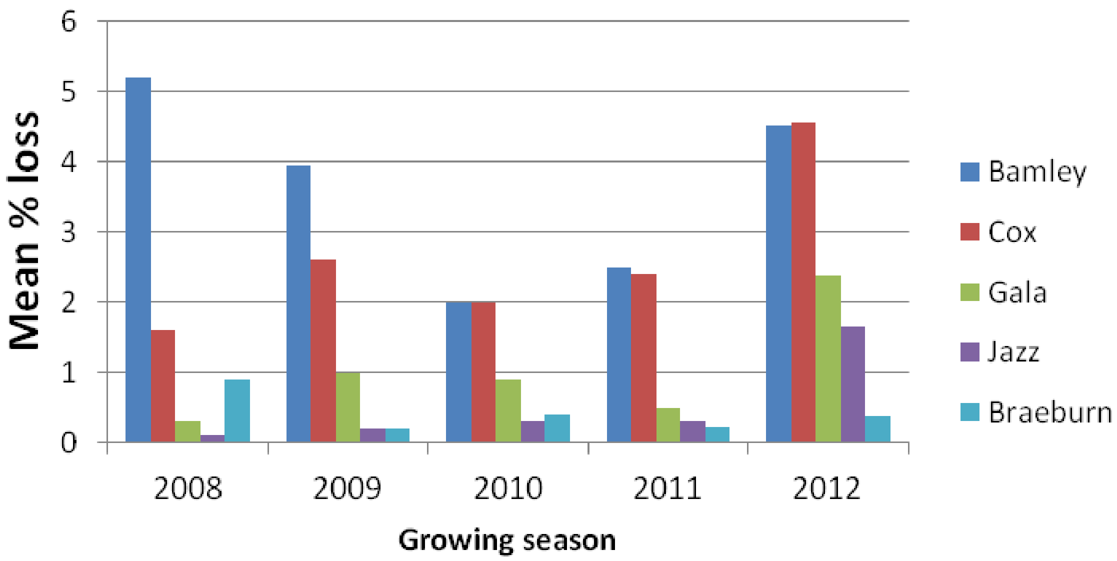

Figure 2. Mean percentage loss by cultivar, survey period 2009-2013.

In addition to the higher than average rainfall during the flowering and early fruiting period resulting in an increase incidence of *Nectria* rot, rainfall was also higher than average at the end of the harvesting period posing an increased *Phytophthora* risk for late harvested apple cultivars. Table 7 shows the *Phytophthora* rot incidence (expressed as % apple samples with *Phytophthora*) in relation to rainfall at East Malling in the 15 days pre harvest in 5 day intervals for 2012 and the previous four growing seasons. The incidence of *Phytophthora* closely correlates with the number of harvest dates which have been identified as high risk (highlighted in red; Table 7). September 2012 was relatively dry with high rainfall occurring from late September and throughout October. As a result *Phytophthora* incidence over the whole season was relatively low (32%) however this increases to 47% in harvests from late September onwards, in line with the predicted *Phytophthora* risk.

Table 7. *Phytophthora* rot incidence (expressed as percentage apple samples with *Phytophthora*) in relation to rainfall at East Malling in the 15 days pre harvest in five day intervals for 2012 and the previous five growing seasons. Apples are considered at risk of *Phytophthora* infection if rainfall is greater than 20mm in the 15 days prior to harvest, at risk harvest dates are highlighted in red.

Harvest date	Rain (EMR) in 15 days pre-harvest > 20mm = risk				
	2008	2009	2010	2011	2012
20 August	-	-	-	9.8	21.6
25 August	-	-	-	22	22
1 September	15.6	3.6	59.4	29	9.6
5 September	29.8	10.4	59.4	35.2	9.6
10 September	42	9.8	22	23.4	4.8
15 September	42.6	25.6	28.8	20	5
20 September	15.8	16.4	29.2	18	5
25 September	4.4	17	9	8.8	53
30 September	8.2	0.8	23.6	8.2	56.2
5 October	25.2	8.4	65.6	6.4	96
10 October	28	37.8	63.6	8.2	73.8
15 October	25.4	38.2	47.4	7.6	72.6
20 October	18.6	34.8	10.6	9.2	60.4
31 October	28.8	9.2	24.4	26.2	56
% apple samples with Phytophthora	**40.7**	**18.6**	**66.7**	**35.7**	**32**

It is important to put the survey data in the context of previous year's data so that a rot profile can be built up over time and trends of emerging and declining pathogens can be determined and related to changes in climate, cultivar or orchard/storage practice. One such trend evident in recent surveys has been the increase in the incidence of *Gloeosporium* rot (Fig. 3). The percentage of apple samples with *Gloeosporium* was between 80-100% in the 2011 and 2012 storage rot surveys. This year's survey observed a significant decrease in *Gloeosporium* incidence, returning to levels observed in the 2010 survey.

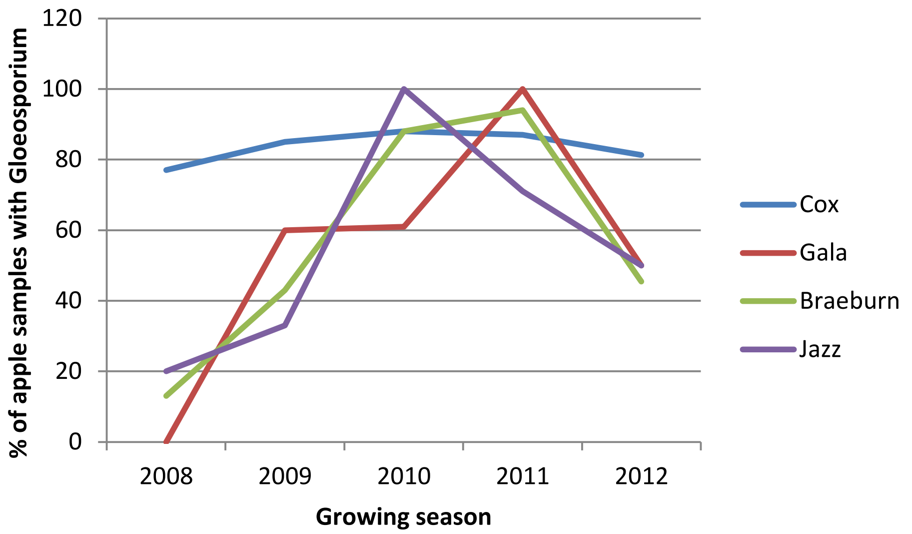

Figure 3. Incidence of *Gloeosporium* rot over the last five rot surveys (2009-2013) in samples of *Gloeosporium* susceptible cultivars (Cox, Gala, Braeburn and Jazz). Rot incidence is expressed as % of apple samples with *Gloeosporium*.

Exploring the possibility of a new pathogen, Gnomonia fragariae, affecting UK strawberry plantations

In 2012 material was collected from a site showing symptoms consistent with those described for *G. fragariae* (Fig 4 a & b). As reported last year, direct isolations from this material were unsuccessful due to faster growing fungi out growing the suspected presence of *G. fragariae*. Material from this sample was also incubated in a moist chamber under UV light at 20°C and monitored for the possible formation of fruiting structures monthly. After four months of incubation fruiting structures characteristic of *Gnomonia* became evident (Fig 4 c & d). Upon dissection of these fruiting structures asci, which are a distinguishing feature within the *Gnomonia* genus, were absent which either suggests that the fruiting bodies were immature or, more likely, that they had already dehisced the ascospores. Isolations of the fungus from the fruiting structures was therefore not possible and neither was absolute confirmation of the causative *Gnomonia* species.

Plant clinic samples (n=3) submitted during 2013 and a sample collected from a site at Home Farm, East Malling, all showed similar symptoms. Samples exhibited slight staining in the crown (Fig. 5a), red/yellow coloured older leaves (Fig. 5 b & e) and black staining of petiole bases (Fig. 5a, b, e & f) with undefined/diffuse lesions on the stems with internally stained vascular tissue. Due to the presence of the black staining at the base of the petiole and other symptoms resembling *G. fragariae* infection these samples were processed with the culturing techniques sensitive to *G. fragariae* isolation (as described in section 2.2).

Verticillium dahliae was isolated consistently for all four samples and *G. fragariae* was not identified in any of the samples. This is not to say that *G. fragariae* is not also present. At the time of writing, petiole samples incubated at 4°C (thought to increase the success rate of isolation (Dr Inga Morocko-Bicevska, pers. comm.)) are to be re cultured to check for the presence of *G. fragariae*.

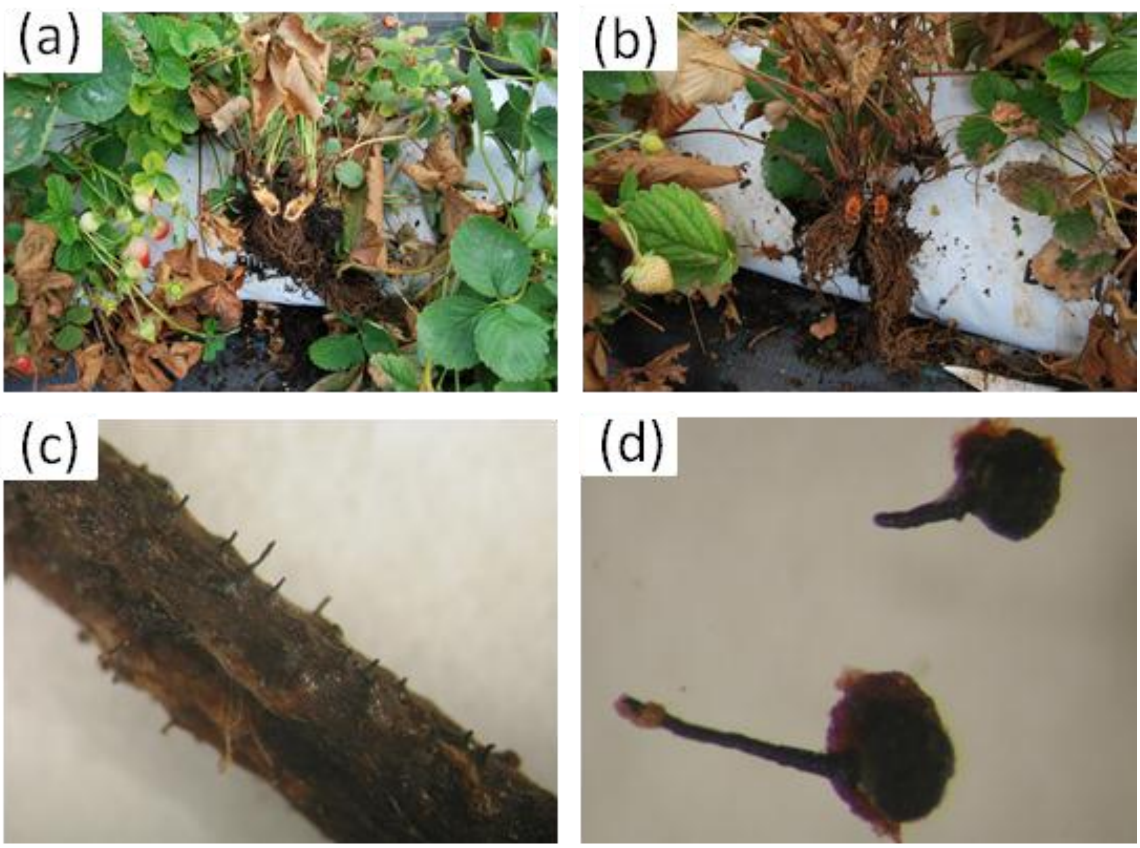

Figure 4.
Field symptoms, (a) and (b), and characteristic fruiting structures, (c) and (d), of *Gnomonia* species following incubation under UV in a damp dish. Samples collected from a site in which the disease was thought to be present following submission of a sample to the plant clinic.

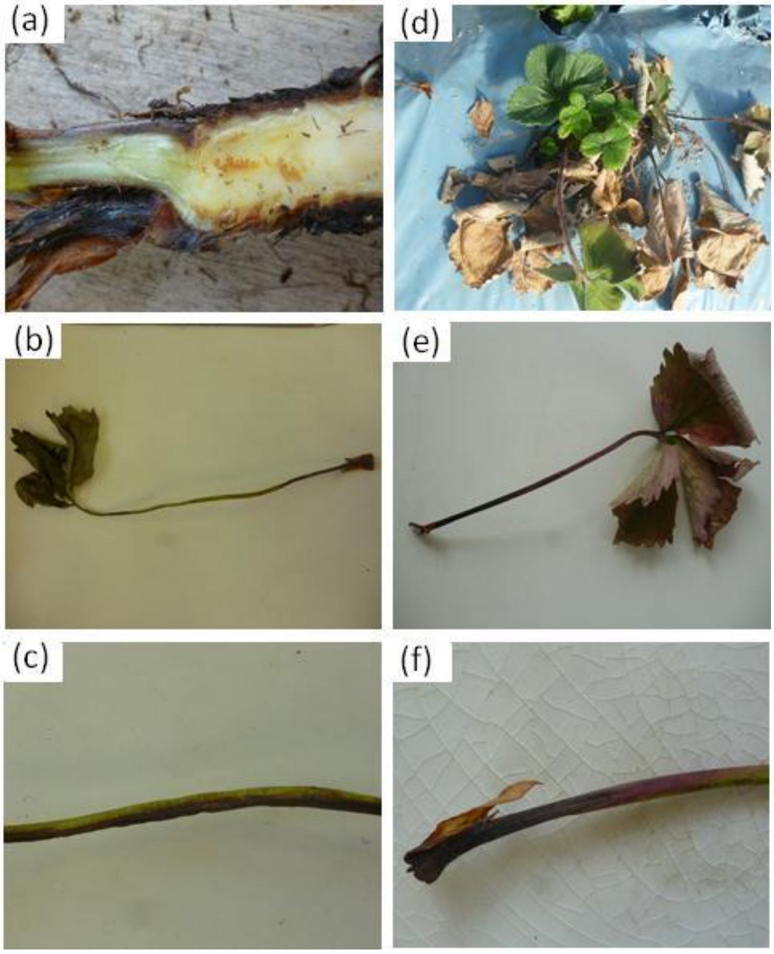

Figure 5.
Typical symptoms of infected material tested for *G. fragariae* in 2013. a-c was submitted to EMR plant clinic. d-e were collected from a site at Home Farm, EMR. (a) shows black rotten petiole bases with slight staining in the crown. (b) and (e) show red/yellow coloured older leaves which coupled with the black rot at the petiole base ((c) and (f) higher magnification) is consistent with the symptoms described for this disease. (d) whole plant symptoms resemble *Verticillium* wilt but for the distinctive black staining at the petiole bases of affected leaves and the fact the plants were grown in recently fumigated soil.

Assessing the effectiveness of responsive apple mildew management through monitoring compared to a routine programme.

Levels of primary blossom mildew (Table 8) were reduced in plots treated by the managed programme through the previous season relative to the routine treated plots however this difference was only statistically significant in cv. Cox.

Levels of primary vegetative mildew (Table 8) was significantly reduced in the managed plot relative to the routine plot following an intensive mildew control programme in the 2012 growing season. Primary vegetative mildew levels still exceed 2% in all four plot x cultivar combinations which is categorised as high primary inoculum in the Apple Best Practice Guide, Defra.

Table 8. % primary blossom and vegetative mildew in Gala and Cox orchards in spring assessments of their second year under managed (treatment rate and interval altered in response to mildew risk) and routine (standard mildew programme) mildew control programmes.

	Plot	Cultivar	
		Gala	Cox
% Primary blossom mildew	Managed	2	7.25
	Routine	2.25	10.5
% Primary vegetative mildew	Managed	2.05	8.80
	Routine	3.01	15.66

Monitoring of secondary mildew levels (Fig. 6; in the managed plot only) was used to inform decisions of treatment rate and interval for the managed programme (Table 3). Secondary mildew levels remained high throughout the monitoring period (>80%). Due to the levels of infection remaining well above the high disease rating threshold (30%) for secondary vegetative mildew an intensive programme was required throughout the season. The routine programme received a total of seven spray applications whilst the managed programme received a total of nine spray applications through the trial period (from full bloom to the end of the season; Table 3).

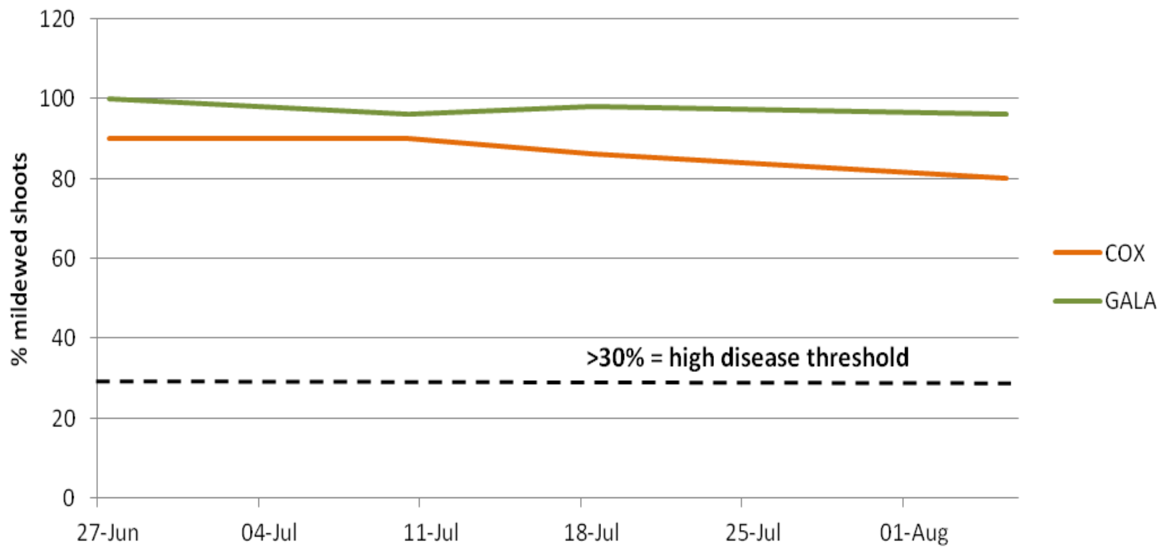

Figure. 6. Mildew monitoring, % mildewed shoots in management plot for cvs. Gala and Cox. Dotted line denotes 30% threshold over which disease rating is considered high.

Full assessments of secondary mildew reveal that mildew control in this orchard was generally poor throughout the 2013 growing season. There were no significant differences of mildew control between the routine and managed programmes at the June assessment. A reduction in secondary mildew levels was observed in the July assessment reflecting the increased efficacy of control expected from a more intensive fungicide programme later in the season.

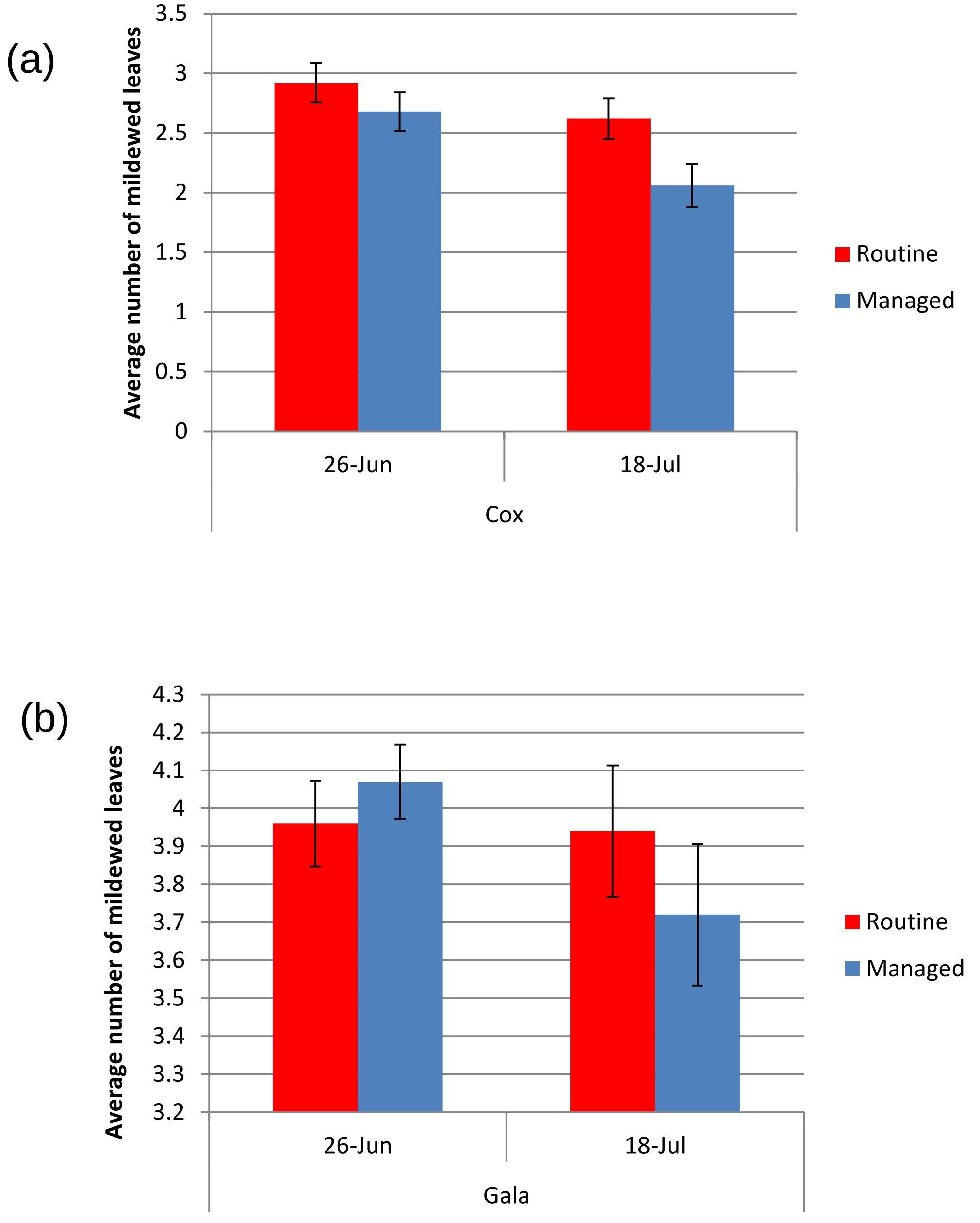

Fig. 4. Full assessments of secondary mildew epidemic levels. (a) and (b) show average numbers of mildewed leaves in top five leaves of shoot on two assessment dates for Cox and Gala respectively.

Discussion

Sustainable control of storage rots of apple

In the 2013 rot survey conducted in this study, rot incidence was relatively high compared with previous years, causing commercially significant losses. This was to be expected due to crucial periods of susceptibility to rot causing pathogens coinciding with periods of high rainfall. Continued high rainfall through the growing season, although coinciding with a period of relative reduced susceptibility of fruit infection, will have promoted the sporulation and spread of canker forming pathogens such as *Nectria* and *Monilinia*, which will have consequences for the subsequent seasons crop. Indeed, increased cankers have been observed during the 2013 growing season, devastating some crops and highlighting the need for increased research focused on this pathogen. At the end of the 2012 harvest period high rainfall continued, which correlates with the increase in *Phytophthora* incidence in line with the predicted risk.

Brown rot (*Monilinia fructigena*) contributed to a large proportion of rots but unlike in previous years was not the dominant rot overall. Instead *Nectria* had the highest overall incidence, increased in importance in the main part due to high levels of rainfall during susceptible periods of fruit development. Cox and Bramley experienced the highest levels of loss (4.6% and 5.2% respectively) consistent with previous years; however some of the newer varieties, which usually experience relatively low levels of loss, in the main part due to reduced storage temperatures relative to Cox and Bramley, did experience high levels of rots. For example, Rubens, Jazz, and Gala were recorded as having 0.1, 0.3 and 0.5% losses respectively whilst this year losses were recorded as 1.7, 1.7 and 2.5%. Increased losses are mostly due to an increase of incidence of *Nectria* rot. Incidentally, these varieties are highly susceptible to *Nectria* canker and despite low storage temperatures the latent infection is still able to express in store, thus emphasising the need for season-long strategies to control rots developing in store.

Due to the rot survey it has been identified that *Gloeosporium* has been increasing in incidence in recent years (between 80 and 100% in 2010 and 2011) however against this trend the incidence in the 2013 rot survey dropped significantly (50%). This is likely to be due to the 2012 growing season experiencing atypical weather conditions compared to recent years. The need for further work to understand this pathogen and to generate control strategies is required. To this end a desk study has been commissioned by the HDC which will enable a review of the European scientific and grower literature and identify areas of future research.

Climatic and orchard factors greatly influence the incidence and type of rot, in addition to this each cultivar has a different rot profile dependent on susceptibility in the field and conditions in store. Through conducting the rot survey it is possible to build up a picture of the limitations of storage, due to rot development, for new varieties and thus advise on season long control to target these rots in the orchard. One such variety is Rubens, which this year experienced large losses due to *Fusarium* core rot. Susceptibility to this rot means that special attention should be made to targeting *Fusarium* during the flowering period.

Despite a delayed start the 2013 growing season has been very favourable for apple production. However the late season has meant that late varieties such as Braeburn will be harvested well into November, coinciding with high rainfall and thus leading to a high risk of *Phytophthora* infection. *Nectria* cankers, which were in abundance this year due to favourable conditions for canker development in 2012 growing season result in a significant *Nectria* rot risk. *Gloeosporium*, although reduced in significance in the 2013 rot survey may increase again due to the warmer temperature experienced during 2013. The rot survey will continue next year.

Exploring the possibility of a new pathogen, Gnomonia fragariae, affecting UK strawberry plantations.

Field and plant clinic samples exhibiting symptoms characteristic of a petiole/crown/root based disease have been examined. A sample, collected last year, which exhibited symptoms consistent with *G. fragariae* but failed to be isolated on agar, did produce fruiting bodies characteristic of *Gnomonia* species (perithecial ascomata immersed in host substrate with central beaks). Although the absence of asci meant that the species could not be definitively confirmed the occurrence and symptoms caused strongly suggest that the causative pathogen is *G. fragariae*, which would be the first recorded outbreak of this disease in the UK.

The other samples tested for the presence of *G. fragariae* were found to be infected with *V. dahliae*. The symptoms observed were atypical of *Verticillium* wilt, which may be due to the environmental conditions this growing season causing an abiotic stress which altered the disease phenotype/plant response. The samples which were confirmed to be infected by *V. dahliae* originated from either soil-less substrates (plant clinic samples) or recently fumigated soil grown crop (Home Farm sample) which suggests that the infection is runnerborne or in the case of the soil grown crop, *V. dahliae* microsclertotia persisted despite fumigation.

Attempts at isolating a UK isolate to categorically confirm the presence of this pathogen in the UK will continue with samples pending and farm visits in 2014. Continued optimisation of isolation techniques aided by collaboration with Dr Morocko-Bicevska (a world authority on *G. fragariae*) will improve the success rate of successful isolation. For example incubation of infected material at 4°C prior to isolation has been shown to enhance success, likely due to the fungus being able to grow at 4°C providing it with an advantage over faster growing competitors (Dr Inga Morocko-Bicevska, pers. comm.). Once a UK strain is isolated, it will be possible to carry out Koch's postulates, to demonstrate that the isolated fungus is able to re infect the host from which it was isolated and exhibit the same symptoms.

Assessing the effectiveness of responsive apple mildew management through monitoring compared to a routine programme.

In 2012, when this trial was initiated, mildew levels were very high. This was in part due to the minimal input of fungicides being applied to the experimental orchard in the years prior to this trial resulting in a build-up of over wintering inoculum, evident from the high levels of vegetative primary mildew recorded in the spring of 2012 (overall average over both plots and cultivars was 15.3%). Through the 2012 growing season greater disease control was achieved on the managed plot, which received 11 fungicide treatments during the trial period, compared to the routine plot which received 7. In the managed plot the average number of mildewed leaves was 1.2 and 2.1 in cvs. Cox and Gala respectively, compared to 5 for both cultivars in the routine plots on the final assessment date.

A key factor for effective control of apple mildew is to maintain primary mildew, the main source of inoculum, at a low level. Primary mildew results from the over wintering of the fungus in the floral and vegetative tissue which sealed up in the previous seasons terminal buds. Therefore, in principle, if good mildew control is achieved in successive seasons, primary mildew will be gradually reduced and the mildew level will be more easily controlled with a reduced reliance on a chemically intensive spray programme. Control achieved during the 2012 growing season in the managed plot relative to the routine plot is reflected in the reduction in blossom and vegetative primary mildew assessments made in the spring of 2013. The levels of primary blossom mildew recorded for cv. Gala in both plots could not be significantly distinguished whilst primary vegetative mildew could. This finding likely reflects the earlier termination of the floral buds relative to vegetative buds in the previous season at which point the mildew epidemic was significantly lower in the managed plot relative to the routine plot.

Despite the reduction observed in primary mildew in the managed compared to routine plots, primary mildew was greater than 2% in both plots. According to the Apple Best Practice Guide, levels of primary mildew on shoots greater than 2% indicate that controlling the mildew epidemic during the season will be problematic.

Through the 2013 growing season regular monitoring of mildew levels in the managed plot revealed that levels remained well above the high disease rating threshold of 30%. Therefore there was no opportunity to reduce fungicide rate or extend spray intervals beyond that of the routine programme. Instead, the managed plot required an intensive fungicide programme throughout the season. This is unfortunate as the increased levels of control achieved in the managed plot in the previous season were expected to reduce the fungicide programme relative to the routine programme in successive years. In addition to the high level of initial inoculums in the trial orchard, poor control may also be attributed to; reduced efficacy of currently available chemistry active against apple mildew due to the emergence of fungicide resistance; the relatively small size of the plots combined with their proximity to neighbouring orchards with high levels of mildew and; the weather conditions during the 2013 growing season being favourable for mildew development and spread resulting in a continuous high risk of mildew infection from external inoculum through the season.

Secondary mildew control was generally poor in the 2013 growing season, however, on the later assessment date mildew levels were reduced in the managed plot, which received a more intensive fungicide programme compared to the routine plot. It is expected that a September assessment would have shown further improvement in mildew control in the managed plot relative to the routine plot however unfortunately this data was not collected due to time constraints in this busy period.

The poor control achieved during the 2013 growing season highlights the poor level of control achieved using the chemistries currently available for apple mildew control. For example, Systhane, an industry standard for apple mildew control is now widely regarded as having poor efficacy due to the development, in certain areas, of strains which have reduced sensitivity. Thus there is a need for new chemistries to become available for apple mildew control. In collaboration with industry the HortLINK project, CP 77 SCEPTRE (sustainable crop and environment protection – targeted research for edibles) is meeting this need through trials and registration of new chemistries and biologicals for key pests, diseases and weeds on horticultural crop groups. The SCEPTRE apple mildew trials are highlighting some promising new chemical and biological products for mildew control. With the efficacy of these products now demonstrated in isolation they will now be trialled in programmes to demonstrate how they can work in commercial orchards.

Conclusions

Sustainable control of storage rots of apple

- The wet growing season of 2012 has led to commercially significant losses to rots in store. *Nectria* has been the dominant rot by incidence and will also have spread in the orchard in the form of wood cankers due to favourable conditions for the pathogen.

- Conversely, a reduced incidence of *Gloeosporium* was observed against the increasing trend of recent surveys, likely to be a climatic factor influencing prevalence.

Exploring the possibility of a new pathogen, Gnomonia fragariae, affecting UK strawberry plantations

- Fruiting bodies characteristic of *Diaporthales* have been identified on a sample which exhibited symptoms consistent with those caused by *G. fragariae.*

- Although not categorically confirmed there is a strong possibility that *G. fragariae* is present in the UK.

Assessing the effectiveness of responsive apple mildew management through monitoring compared to a routine programme

- A reduction in primary mildew was observed in the managed plot relative to the routine plot following the previous year of this trial which achieved a good level of control of secondary mildew.

- Secondary mildew control was poor during the 2013 growing season despite the managed plot receiving an intensive mildew control programme highlighting the reduced efficacy of currently available apple mildew control products. The SCEPTRE project is addressing the need for new control options.

Knowledge and Technology Transfer

Presentation of fellowship project results have been made at various forums (see 'summary of progress' section). A fellowship trainee profile and description of fellowship project work has also been featured in HDC news and trade press (e.g. the fruit grower)

Appendices

Appendix 1; Raw data from apple rot survey 2012/13 summarised in table within report

Pack house	Date Assessed	Date Picked	Cultivar	*Brown rot*	*Botyrtis*	*Phytopthora*	*Penicillium*	*Nectria*	*Gleosporium*	*Fusarium*	*Mucor*	*Botryosphiria*	*Phomopsis*	Stalk	Eye	Cheek	Core	Loss (%)
Mansfields	21/2/13	15/10/12	Braeburn	32.3	16.1	3.2	4.8	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Mansfields	14/2/13	17/10/12	Braeburn	91.7	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Mansfields	13/3/13	17/10/12	Braeburn	26.1	0.0	0.0	4.3	60.9	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Bardsley	20/2/13	23/10/12	Braeburn	17.0	12.3	1.9	9.4	14.2	39.6	0.0	0.9	0.0	0.0	0.9	0.0	0.0	3.8	0.1
Amsbury	20/2/13	26/10/12	Braeburn	1.3	6.6	61.8	5.3	5.3	7.9	0.0	10.5	0.0	0.0	0.0	1.3	0.0	0.0	0.5
Mansfields	31/1/13	31/10/12	Braeburn	74.1	0.0	0.0	13.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Mansfields	17/1/13	30/11/12	Braeburn	0.0	22.2	0.0	0.0	55.6	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amsbury	15/1/13	##/10/12	Braeburn	0.0	9.1	15.9	0.0	63.6	0.0	0.0	11.4	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Bardsley	6/3/13	??	Braeburn	10.0	0.0	0.0	4.4	28.9	0.0	36.7	0.0	0.0	0.0	10.0	1.1	0.0	8.9	0.1
		Braeburn Average		28.0	7.4	9.2	5.5	31.7	8.7	4.1	2.5	0.0	0.0	1.2	0.3	0.0	1.4	0.3
Bardsley	27/2/13	5/9/12	Cox	11.9	0.0	0.0	0.0	85.7	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
Bardsley	6/3/13	6/9/12	Cox	22.4	1.6	0.0	0.0	74.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
Bardsley	30/1/13	7/9/12	Cox	72.0	12.0	0.0	0.0	8.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
NNF	13/3/13	10/9/12	Cox	23.6	9.1	0.0	5.5	56.4	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
The Breach	15/1/13	10/9/12	Cox	61.5	0.0	0.0	3.8	7.7	0.0	19.2	0.0	0.0	0.0	0.0	0.0	0.0	7.7	7.0
The Breach	23/1/13	11/9/12	Cox	0.0	75.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
The Breach	6/3/13	11/9/12	Cox	80.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5
The Breach	13/2/13	14/9/12	Cox	59.1	1.1	0.0	1.1	21.6	0.0	11.4	0.0	0.0	1.1	0.0	0.0	0.0	4.5	2.0
Mansfields	7/2/13	16/9/12	Cox	8.0	0.0	2.0	0.0	90.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
Mansfields	14/2/13	17/9/12	cox	7.0	5.3	7.0	1.8	14.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.2	2.0
Mansfields	6/3/13	17/9/12	Cox	3.2	6.5	16.1	0.0	74.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5

NNF	21/2/13	17/9/12	Cox	70.0	0.0	0.0	0.0	26.7	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Mansfields	21/2/13	19/9/12	Cox	23.5	3.9	3.9	0.0	68.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5
NNF	24/1/13	19/9/12	Cox	47.7	6.2	0.0	15.4	13.8	12.3	0.0	3.1	1.5	0.0	0.0	0.0	0.0	0.0	3.0
Mansfields	24/1/13	21/9/12	Cox	68.8	0.9	0.5	2.7	6.3	12.7	0.0	1.4	0.9	0.0	0.0	0.0	0.0	5.9	2.5
Mansfields	13/3/13	??	Cox	66.7	0.0	6.7	0.0	23.3	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
			Cox Average	39.1	7.6	2.3	4.7	35.7	3.2	1.9	0.3	0.2	0.1	0.0	0.0	0.0	5.1	4.6
The Breach	6/3/13	19/9/12	Gala	16.4	0.0	0.0	10.9	67.3	0.0	0.0	0.0	0.0	0.0	3.6	0.0	1.8	0.0	3.0
The Breach	27/2/13	20/9/12	Gala	16.7	0.0	2.8	5.6	75.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Mansfields	6/3/13	21/9/12	Gala	77.8	0.0	0.0	11.1	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Mansfields	13/3/13	21/9/12	Gala	42.5	0.0	0.0	1.4	53.4	1.4	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.0
NNF	21/2/13	21/9/12	Gala	68.8	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	6.3	0.0	0.1
The Breach	13/3/13	21/9/12	Gala	47.7	20.5	2.3	9.1	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	8.0
Mansfields	7/2/13	22/9/12	Gala	5.8	18.8	4.3	2.9	14.5	10.1	0.0	18.8	0.0	0.0	10.1	0.0	2.9	11.6	3.0
NNF	6/3/13	22/9/12	Gala	2.1	2.1	10.6	2.1	83.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Mansfields	31/1/13	24/9/12	Gala	47.2	9.7	0.0	8.3	29.2	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Mansfields	24/1/13	27/9/12	Gala	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
The Breach	6/2/13	28/9/12	Gala	29.5	9.1	0.0	2.3	22.7	34.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	5.0
Mansfields	17/1/13	29/9/12	Gala	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	5.2	91.4	0.5
NNF	31/1/13	29/9/12	Gala	34.6	0.0	0.0	23.1	7.7	1.9	7.7	0.0	0.0	0.0	7.7	0.0	3.8	13.5	0.5
Amsbury	20/3/13	9/10/12	Gala	4.8	3.2	1.6	4.8	83.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
			Gala Average	28.1	11.8	1.5	6.7	33.3	3.9	0.5	1.3	0.0	0.0	2.5	0.1	1.4	8.6	2.4
Amsbury	30/1/13	10/10/12	Jazz	35.6	17.3	1.0	11.5	12.5	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Mansfields	17/1/13	23/10/12	Jazz	81.0	6.9	0.0	0.0	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	1.5
Mansfields	14/2/13	24/10/12	Jazz	42.5	0.9	0.0	0.0	19.5	32.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	1.0
Amsbury	6/3/13	29/10/12	Jazz	0.0	5.0	21.7	11.7	50.8	5.0	0.0	4.2	0.0	0.0	0.8	0.0	0.0	0.8	4.0
			Jazz Average	39.8	7.5	5.7	5.8	22.9	15.2	0.0	1.0	0.0	0.0	0.2	0.0	0.0	2.2	1.7
Bardsley	6/2/13	26/9/12	Rubens	65.6	0.0	3.1	3.1	3.1	0.0	0.0	0.0	0.0	0.0	6.3	3.1	4.7	12.5	2.0
Bardsley	13/2/13	26/9/12	Rubens	16.7	4.2	0.0	0.0	75.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Bardsley	15/1/13	4/10/12	Rubens	13.2	1.5	0.0	2.9	82.4	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.1

			Rubens Average	31.8	1.9	1.0	2.0	53.5	1.4	0.0	0.0	0.0	0.0	2.6	1.0	1.6	4.2	1.7
NNF	14/2/13	9/10/12	Cameo	13.0	73.9	4.3	0.0	4.3	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5
NNF	7/2/13	10/10/12	Cameo	2.3	0.0	83.7	4.7	2.3	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
NNF	17/1/13	25/10/12	Cameo	72.7	2.3	0.0	11.4	4.5	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	6.8	1.5
NNF	31/1/13	26/10/12	Cameo	37.5	0.0	0.0	12.5	37.5	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
			Cameo Average	31.4	19.0	22.0	7.1	12.2	4.9	0.6	1.1	0.0	0.0	0.0	0.0	0.0	1.7	0.8
Bardsley	23/1/13	19/9/12	E. Russet	70.7	4.0	0.0	3.0	15.2	6.1	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5
NNF	24/1/13	20/9/12	E. Russet	26.7	13.3	40.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	6.7	6.7	0.0	0.1
The Breach	30/1/13	22/9/12	E. Russet	57.1	0.0	0.0	3.6	32.1	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	7.1	0.5
Mansfields	21/2/13	28/9/12	E. Russet	0.0	0.0	0.0	0.0	71.4	0.0	0.0	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Mansfields	7/2/13	2/10/12	E. Russet	8.3	0.0	0.0	4.2	16.7	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.7	2.0
Mansfields	14/2/13	??/09/12	E. Russet	5.2	36.2	0.0	12.1	6.9	32.8	0.0	0.0	0.0	0.0	1.7	0.0	1.7	3.4	0.5
			Egremont Russet Average	28.0	8.9	6.7	3.8	23.7	8.3	0.6	4.8	0.2	0.0	0.3	1.1	1.4	12.9	0.7
Mansfields	17/1/13	30/9/12	Empire	0.0	5.9	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0	5.9	0.0	82.4	0.5
Amsbury	27/2/13	30/10/12	Envey	0.0	66.7	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<1
Amsbury	13/3/13	10/10/12	Falstaff	12.9	3.2	0.0	0.0	22.6	16.1	0.0	16.1	0.0	0.0	0.0	0.0	0.0	29.0	3.0
Amsbury	13/2/13	??	Fuji	0.0	12.5	0.0	0.0	37.5	0.0	0.0	0.0	0.0	0.0	4.2	4.2	0.0	41.7	1.0
Mansfields	6/3/13	18/10/12	G. Delicious	52.2	0.0	0.0	30.4	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	4.3	0.1
Mansfields	13/3/13	18/10/12	G. Delicious	7.6	0.0	6.3	1.3	83.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Mansfields	24/1/13	23/10/12	Ida Red	61.1	0.0	0.0	0.0	30.6	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.5
Amsbury	23/1/13	2/10/12	jonagold	3.8	3.8	47.5	2.5	3.8	38.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
			Other dessert Average	17.2	11.5	10.9	4.3	23.3	7.8	0.3	2.0	0.0	0.0	0.5	1.3	0.5	20.4	1.0
The Breach	20/6/13	24/8/12	Bramley	31.3	19.8	1.0	4.2	30.2	0.0	12.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Mansfields	6/3/13	27/8/12	Bramley	11.8	11.8	2.9	0.0	70.6	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Amsbury	27/3/13	3/9/12	Bramley	42.5	1.9	0.6	1.9	51.9	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	7.0
Mansfields	14/2/13	5/9/12	Bramley	30.0	10.0	0.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Bardsley	20/3/13	7/9/12	Bramley	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.9	3.0
The Breach	20/3/13	7/9/12	Bramley	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
Mansfields	24/1/13	8/9/12	Bramley	1.9	17.3	0.0	1.9	15.4	34.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.8	1.5

The Breach	27/3/13	17/9/12	Bramley	51.9	0.0	0.0	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.5	15.0
Mansfields	13/3/13	19/9/12	Bramley	11.8	11.8	41.2	11.8	0.0	17.6	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	10.0
Amsbury	6/3/13	??	Bramley	36.3	0.0	0.0	1.0	8.8	0.0	0.0	0.0	0.0	0.0	43.1	1.0	1.0	8.8	5.0
The Breach	20/2/13	??	Bramley	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
			Bramley Average	20.6	6.6	4.2	2.0	39.8	4.8	1.1	0.4	0.1	0.0	3.9	0.6	0.1	15.8	5.2
	Overall average			**29.1**	**9.1**	**5.7**	**4.7**	**31.9**	**5.8**	**1.3**	**1.4**	**0.1**	**0.0**	**1.4**	**0.4**	**0.5**	**8.8**	**2.6**

Appendix 2; Fact sheet on *Gnomonia fragariae* deseminated to agronomists to raise awareness of this disease

Gnomonia fragariae

> A disease affecting the petioles and roots causing severe stunting and collapse of plants.
> Symptoms include discolouration and collapse of outer leaves resulting from an upward developing black rot on petiole bases which girdles the stem, black lesions on roots and discolouration in crown.
> Symptoms may be mistaken for crown rot, black lesions on roots and petioles are a distinguishing feature.

Picture credits: Inga Morocko-Bicevska