Project title:	Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management
Project number:	HL0191, SF94
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Report:	Annual report, year 4 (issued 18 April 2012)
Date commenced:	1 April 2008
Expected completion date:	31 March 2013

Key words: Strawberry, Integrated Pest Management, grey mould, *Botrytis cinerea*, mildew, *Podospheara aphinis*, strawberry blossom weevil, *Anthonomus rubi*, European tarnished plant bug, *Lygus rugulipennis*, trap cropping, bug vac, Lucerne, strawberry aphids, biocontrol

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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.

GROWER SUMMARY

Headline

New control approaches have been developed for the main pests and diseases of strawberry and these have been combined into a new Integrated Pest and Disease Management programme which will reduce pesticide use and greatly reduce the incidence of pesticide residues.

Background and expected deliverables

The overall aim of the project is to develop alternative, sustainable, non-pesticidal methods for managing Botrytis, mildew, black spot, aphids, blossom weevil and capsid bugs on strawberry so greatly reducing (by >50%) pesticide use and eliminating the occurrence of reportable pesticide residues on harvested fruit. The methods developed for the individual pests and diseases will be combined with existing non-chemical methods for other pests and diseases in an overall Integrated Pest and Disease Management (IPDM) system, and this will be tested and refined in commerical strawberry production over 2 seasons.

Summary of project and main conclusions

Progress on each objective of the project is summarised below

Powdery mildew

Experiments were conducted to investigate whether manipulation of nitrogen via fertigation within commercially acceptable ranges could significantly affect powdery mildew development on strawberry plants of cultivar Elsanta. The results showed that increasing nitrogen input via fertigation led to increased mildew development. However, the reduction in mildew development under low nitrogen input is rather limited and, therefore, may be considered for practical purposes to be neutral on powdery mildew development on strawberry under protection.

Black spot

Pathogenicity of black spot isolates from different hosts on strawberry fruit

In November 2011 the pathogenicity of 14 isolates of black spot (*Colletotrichum acutatum*) collected from various apple cultivars, alder, cherry, willow herb and primula on strawberry fruits was tested by inoculating strawberry fruits of cv. Premier with spore droplets of the isolates. All isolates developed sporing lesions on the strawberry fruits but it was not possible to measure aggressiveness as the incidence of botrytis fruit rot was also high on the fruit. The tests will be repeated in spring 2012.

Pathogenicity of black spot isolates from different hosts on strawberry plants

In December 2010 strawberry plants cv. Elsanta were inoculated with 13 isolates of *Colletotrichum acutatum* obtained from different hosts, including strawberry, apple, willow herb, alder and Primula to test the pathogenicity of the isolates on strawberry plants. Black lesions or reddish spots developed on the petioles of most plants inoculated. However, a few lesions were also observed on the uninoculated controls. None of the lesions on the plants were observed to be sporing with *C. acutatum.* Some of the petioles with lesions were subsequently checked for *C. acutatum* using paraquat and sporing colonies of *C acutatum* were detected indicating that the black spot isolates from non-strawberry hosts could also attack strawberry. The plant tests will be repeated in April 2012 using younger runners.

Evaluation of biofumigants to eliminate Colletotrichum-infested debris in soil

The purpose of this study was to evaluate the efficacy of biofumigants against *C. acutatum* in the laboratory based on the protocol developed for *Verticillium dahliae* testing. The biofumigants evaluated were Biofence, based on mustard and an experimental product based on lavender waste. Blackspot-infested strawberry debris was placed in soil in crates in which either Biofence or lavender waste had been added. Strawberry debris was removed at intervals and plated on to a selective media to check for *C. acutatum*. Final evaluation of the plates is still in progress.

European tarnished plant bug

Use of hexyl butyrate as a repellent: In April and in June *L. rugulipennis* were caught in bucket traps containing the sex pheromone alone, but none were trapped where hexyl butyrate dispensers were included indicating that hexyl butyrate was repelling the males. In September only 1 *L. rugulipennis* was caught in the pheromone traps and none in the hexyl butyrate traps although males were present in the field at this time indicating that the adults were not responding to the pheromone at this time in the season. In replicated experiments designed to test the range of influence of the hexyl butyrate dispensers, at 1m spacing no *L. rugulipennis* males were caught in pheromone traps whereas at larger spacings they were indicating a relatively short distance effect.

The use of a bug-vacuum reduced numbers of *L. rugulipennis* on strawberry to approximately half that of an untreated control area, and comparable to an area that had received an insecticidal spray of Calypso.

Strawberry blossom weevil super trap

The possiblity of a single combined trap for strawberry blossom weevil and Europen tranished plant bug was investigated. A green cross vane bucket trap without excluder grid and batedwith lures for both A rubi and L rugulipennis was found to be effective.

IPDM

IPDM Strategy

An integrated pest and disease management programme was devised by combining the results from objectives 1-6 on the six specified pests and diseases together with existing established non-chemical control methods. For diseases the strategy comprised three aspects:

- Reduction of initial inoculum
- Development of risk-assessment system for better timing of management practices
- Increased use of BCAs and natural products during flowering.

For insect pests an integrated approach using habitat manipulation, semiochemical lures, biocontrol agents together with more species specific control was developed. These systems were evaluated in large commercial plots. Where treatment is required, priority was given to use of natural products and commodity substances, the use of biocontrol (e.g. aphids) or the

use of conventional fungicides or insecticides only when a need was identified and the risk of leaving a residue in fruit was assessed as low. Pesticides which have been found to leave detectable residues in fruit, were not, wherever an alternative treatment or chemical was available, used on fruit.

Evaluation of IPDM Strategy

The IPM strategy devised was tested in comparison with the standard commercial programme used at the time by the host farmer, at three sites in England, one in Surrey at Tuesley Farm and two in Kent at Norham Farm and Langdon Manor Farm. The new strategy and the 'standard commercial programme' control were applied to large plots of protected strawberries. The Tuesley Farm site was planted with var. Elsanta on 28th March 2010, the Norham farm site was planted with var. Sonata on 16 May 2011 and the Langdon Manor Farm site was planted with var. Amesti in early April. The results for Tuesley Farm and Langdon Manor Farm are summarised below.

Tuesly farm

- The utilisation of the fungicide Serenade ASO (*Bacillus subtilis*) prior to the use of bumble bees to disperse Prestop Mix (*Gliocladium catenulatum*) to the flowering crop for botrytis control (under Extrapolated Experimental Approval) resulted in no residues in the fruit and no difference in levels of botrytis when compared to a standard grower program.
- Powdery mildew control in the IPDM tunnels was based on a forecasting model utilising in-crop temperature, humidity and disease levels. 7 Potassium bicarbonate applications were used in response to a risk warning. This reduced the number of otherwise weekly fungicide applications against powdery mildew and hence, together with the use of potassium bicarbonate eliminated residues. Levels of mildew were higher in the IPDM area but never reached damaging levels.
- In comparison 9 fungicides were applied for Botrytis through establishment flowering and harvest and a further 9 fungicides plus potassium bicarbonate and sulphur were applied to the GS tunnel for powdery mildew.
- Strawberry blossom weevil numbers in traps and levels of damage were low, awareness of this through monitoring allowed the decision not to apply Calypso (thiacloprid) which was the only insecticide residue present in the GS fruit.
- Aphid numbers at Tuesley farm were greater in the IPDM tunnels in early June but were successfully brought under control through the use of Aphidsure Fragaria (mix of 6

aphid parasitoids) and the use of a maltodextrin spray resulting in no need to apply a conventional insecticide.

- The use of a high rate of *Phytoseilus persimilis* for two spotted spider mite control instead 2 insecticides resulted in slightly higher numbers in the IPDM tunnels compared to the GS but these never reached damaging levels and predatory mites were always visible alongside the pest, this allowed insecticidal control to be delayed until after harvest.
- Other pests were not present in high enough numbers to warrant insecticidal control through flowering and harvest, resulting in no residues on the fruit
- The use of biological control agents either a formulation for dispersal by bees, or by spray application to flowers, together with the use of potassium bicarbonate in conjunction with powdery mildew risk forecasts resulted in no significant differences overall in yield or in the relative proportions of Class 1 and 2 fruit due to fungal diseases.
- The use of biological control agents as insect predators released into the crop as well as low pest pressure in this season resulted in no real differences in pest damage to fruit with only minimal thrips and slug damage to fruit in both programs, causing no differences overall in yield or in the relative proportions of Class 1 and 2 fruit.

Langdon Manor Farm

- Honey bees were used to disperse Prestop Mix (*Gliocladium catenulatum)* for Botrytis control*.* These were introduced at the start of flowering on 17 June and remained for 6 weeks. No other controls for Botrytis were applied during this period. This programme resulted in Botrytis incidence in the fruit similar to that from fruit in the grower plot and no residues detected in the fruit. In the grower tunnels a total of 8 sprays were applied for Botrytis control in the same period.
- Powdery mildew control in the IPDM tunnels was based on a forecasting model utilising in-crop temperature, humidity and disease levels. A total of 12 sprays were applied for powdery mildew control in the IPDM plots. This total includes some pre-flowering sprays and post-harvest sprays. A total of 23 sprays were applied to the grower plots for mildew. Levels of mildew were slightly higher in the IPDM area but never reached damaging levels.
- Strawberry blossom weevil numbers in traps and levels of damage were low, awareness of this through monitoring allowed the decision not to apply an insecticide for this pest in the IPDM area.
- Aphid numbers were successfully brought under control in the IPDM area through the repeated use of a mix of 6 aphid parasitoids resulting in no need to apply a conventional insecticide.

- *Phytoseilus persimilis* was used in the IPDM area in late May and late June for the control of two spotted spider mite. The number of plants infested with two-spotted spider mite was identical for both treatments. Pest numbers declined by late July. No insecticide was used in the IPDM area, whilst the grower standard received sprays in mid-July.
- *Neoseiulus cucumeris* (as slow release sachets) was used in the IPDM area in late April and early June for the control of thrips. Phytoseiids were also found in the grower standard area. Thrips numbers showed a similar pattern in both the IPDM and grower standard areas.
- *Lygus rugulipennis* males were caught in high numbers in pheromone traps in late-August. Nymphs from this generation were found in higher numbers on an alyssum trap crop than in the strawberry crop. There was no difference in damage due to this pest between the grower standard and the IPDM areas.
- Other pests were not present in high enough numbers to warrant insecticidal control through flowering and harvest, resulting in no residues on the fruit.
- The use of biological control agents as insect predators released into the crop resulted in no real differences in pest damage to fruit between the grower standard and IPDM areas, causing no differences overall in yield or in the relative proportions of Class 1 and 2 fruit.

Financial benefits

Botrytis, mildew, black spot, aphids, blossom weevil and capsid bugs are very common problems wherever and however strawberries are grown in the UK. A very high percentage of strawberry plantations are infected by these pests and diseases. No quantitative data on losses is available but conservatively assuming 10% of the crop is lost as a result of these infestations, this is equivalent to 5,074 tonnes of strawberries, worth £21 million. To calculate the expected annual added value that might result from a successful project, it is assumed that it will lead to an average halving in losses in the current crop to 5%, i.e. an additional £10,623 million of UK sales. In addition, the improved consumer acceptability of UK strawberry growing compared to foreign competitors will reduce imports by 10%, yielding an additional £17 million of sales. It is possible that increased consumer confidence in strawberries will also grow the overall market marginally.

Action points for growers

- The risk of Botrytis on early covered June-bearer strawberries is very low so spraying with fungicides against Botrytis may not be necessary. For everbearers later in the season, the EMR Botem computer-based forecasting model (available from Prof Xiangming Xu at EMR, xiangming.xu@emr.ac.uk) can be used to time sprays of fungicides or biocontrol agents and may result in a substantial reduction in fungicide use.
- Effective early control of powdery mildew is essential to minimise the risk later in the crop and if such good early control is achieved then a computer based forecasting model available from EMR can be used to time sprays and may result in a substantial reduction in fungicide use.
- For practical purpose, the effect of increasing nitrogen input via fertigation on mildew development is minimal. Thus, growers can adjust their fertigation primarily on the basis of plant and fruit development without the need to consider the effect on powdery mildew
- Sex pheromone traps for monitoring European tarnished plant bug, a serious pest of late season strawberry, and for the Common Green Capsid, have been developed and are now commercially available for the 2012 season.
- Application of a late season spray of an aphicide (e.g. Claypso) in late October or November will greatly reduce populations of several of the most damaging and common aphid pests of strawberry and result in greatly reduced aphid populations the following spring, possibly obviating the need to spray. New formulations of mixtures of aphid parasitoid species are available from biocontrol suppliers and can be introduced in spring to help keep spring populations low.
- An Integrated Pest and Disease Management programme which should reduce the use of pesticides and greatly reduce the incidence of residues on fruits at harvest has been devised and is being tested for a second year on a large scale on three commercial farms in 2012-13.

SCIENCE SECTION

Objective 1. To develop an IPM system for powdery mildew through reducing initial inoculum levels in planting material, microbial biocontrol, use of natural products, and reducing plant susceptibility to disease through adjustment of N fertiliser application

Task 1.1 Detection and reduction of inocula in planting material (Y1-4)

We have two batches of tray plants of CV. Sonata delivered from a commercial grower in May and June. These tray plants were incubated in CE cabinets at 15°C to assess whether there was latent mildew on these plants. As in previous years, we did not observed any mildew on these plants.

Task 1.2 Effect of nitrogen on the susceptibility to powdery mildew (Y3-4, EMR)

Methods

Two treatments were tested: normal and high nitrogen input during the fruiting period. Peat growing bags were used; 10 cold-stored runners of cv. Elsanta were planted in each bag. Initially all plants from both treatments were subjected to the same fertigation regime before flowering; the master concentration of fertigation was: N – 120 mg/l, P – 45 mg/l, K – 176 mg/l, Ca – 71 mg/l, Mg - 20 mg/l, Na - 37.4 mg/l, CI – 48 mg/l and S – 18 mg/l. After blossom, plants in the high nitrogen treatment received fertigation with the master concentration of N – 197 mg/l, P – 45 mg/l, K – 203 mg/l, Ca – 71 mg/l, Mg - 42 mg/l, Na - 37.4 mg/l, CI – 48 mg/l and S – 18 mg/l; whereas plants in the normal nitrogen regime received fertigation with the master concentration of N – 128 mg/l, P – 45 mg/l, K – 248 mg/l, Ca – 71 mg/l, Mg - 42 mg/l, Na - 37.4 mg/l, CI – 48 mg/l and S – 63 mg/l.

In total, 16 growing bags (i.e. 160 plants) were used in the experiments, which were conducted in the confined GroDome compartment (day temperature – 22°C and night 16°C). Fig. 1.2.1 shows the exact experimental set-up of the 16 grow bags):

N H N H
H N H N
N H N H
H N H N

Figure 1.2.1. Experimental set up of 16 grow bags allocated to normal (N) and high (H) nitrogen treatment.

Irrigation and fertigation were delivered to plants via four irrigation lines, each with separate controls; two of these were randomly allocated to each treatment. Twenty drippers were attached to each irrigation line at a regular interval; five of 20 drippers were then inserted to each grow bag. The amount of water used to irrigate plants was such that the moisture content inside the grow bag was around the maximum holding capacity (determined in preliminary experiments using the same type of the bags) but without excess leaking of water from the bag. Moisture content in the growing media was checked daily. If necessary, the amount of irrigation water was adjusted. In general, apart from the first few days of the blossom period, each bag received about 2 L water per day. The master fertigation solution was mixed with irrigation water at a ratio of 1:100 via a control and delivered to each bag.

Two weeks after the onset of flowering, 20 mildewed plants were systematically placed between grow bags. These mildewed plants were placed about 10 cm higher than the plants in grow bags in order to facilitate spore dispersal to experimental plants. Mildew was assessed three weeks later. This experiment was conducted twice in 2010: the first from late May to early August, and the second from mid-August to mid-October. This experiment was repeated again in May-July 2011. Data from these three experiments were statistically analysed together and presented here.

Results

Severe mildew developed in all three experiments (Fig. 1.2.2), with a minimum leaflet incidence of 62% per treatment; there was large variation in mildew severities or colony number among leaflets (Fig. 1.2.3). The high nitrogen treatment consistently resulted in greater mildew development in all three experiments. The difference in the mildew incidence between the normal and high nitrogen treatments was restive 4%, 8% and 3% in the three experiments, with corresponding differences of 3% in percentage leaf area with mildew, or 0.7 and 1.2 colonies per leaflets (Fig. 1.2.2). The treatment differences in the two variables were statistically significant ($P < 0.05$).

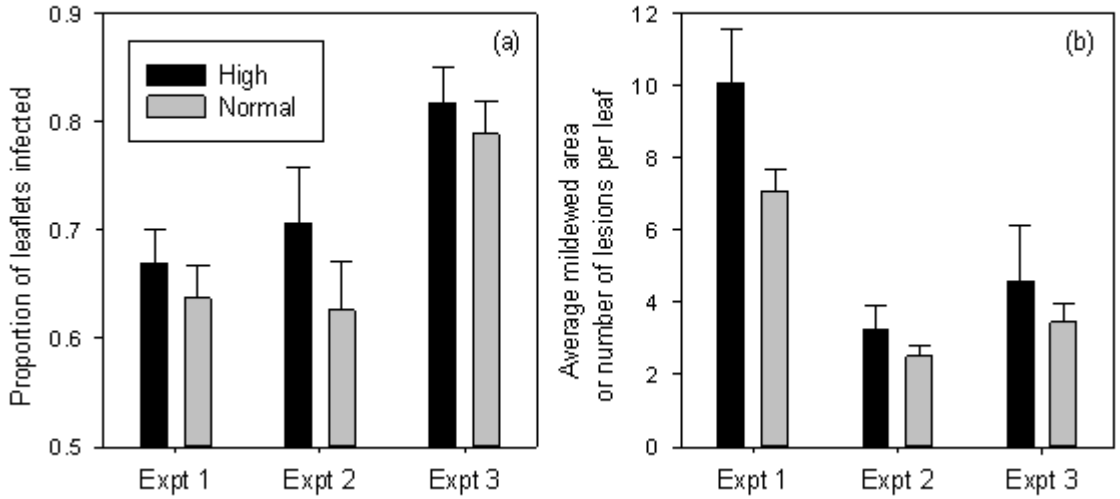

Figure 1.2.2 Incidence of strawberry leaflets with powdery mildew (a) and average percentage leaf area mildewed (Expt 1) or number of lesions per leaflets (Expt 2 & 3) (b) where strawberry plants of cv. Elsanta were subjected to two levels (High & Normal) of nitrogen input post-blossom via fertigation. Plants were inoculated with powdery mildew two weeks after the onset of differential fertigation treatments and assessed for powdery mildew three weeks after inoculation.

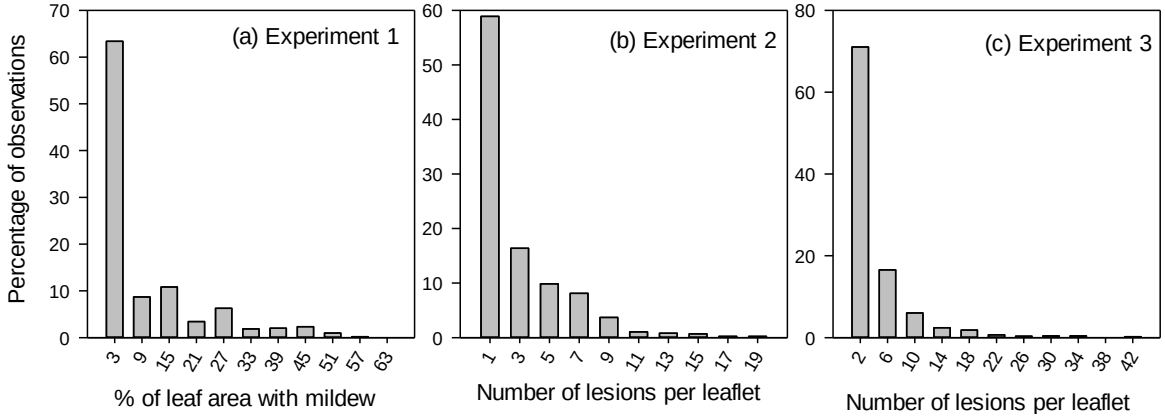

Figure 1.2.3 Histogram of percentage leaf area with powdery mildew (a) or number of mildew colonies on each individual leaflet of strawberry plants (cv. Elsanta) that were subjected to two levels (High & Normal) of nitrogen input post-blossom via fertigation. Plants were inoculated with powdery mildew two weeks after the onset of differential fertigation treatments and assessed for powdery mildew three weeks after inoculation.

Discussion

The effect of differential nitrogen input on strawberry powdery mildew development is significant but smaller than for powdery mildew on other powdery mildew diseases. This is due probably to the relatively small differences in the nitrogen input between the two treatments. In the present experiment, compared to the normal nitrogen treatment, the high nitrogen treatment had about 54% more nitrogen input (128 vs. 197), a small difference compared with many other studies where greater effects of nitrogen concentration on powdery mildew development were demonstrated. For example, three levels of 0, 150 and 300 kg ha^{-1} were used to study the foliar nitrogen concentration on powdery mildew on wheat (Chen, Zhang et al. 2007). In another study on barley powdery mildew, the rate of nitrogen input ranged from 30 to 240 mg per pot (Jensen and Munk 1997). The key point in this study is not to demonstrate where there is effect of different nitrogen concentrations on mildew development rather to study whether nitrogen concentrations within the range that does not cause crop losses or adversely affect quality influence powdery mildew development. Fertiliser input in the strawberry production under protection is currently well managed via fertigation. Thus the scope for large reduction in nitrogen usage is unlikely without adversely affecting crop yield and fruit quality. Nevertheless, even a small reduction in nitrogen use may have significant impact on commercial horticulture.

A few studies showed that high nitrogen application rate did not affect percentage leaf area with mildew but resulted in increased spore production of powdery mildew on tomato (Hoffland, Jeger et al. 2000), and barley (Jensen and Munk 1997). Although spore production was not assessed in the present study, there was no apparent difference in the sporulation activity based on visual assessment.

In conclusion, present results agree with current consensus on the effect of nitrogen on powdery mildew development. However, the reduction in mildew development under low nitrogen input is rather limited and, therefore, these treatments can be considered for practical purposes to be neutral on powdery mildew development in relation to the current best practice adopted in strawberry production under protection.

Literature cited

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Hoffland, E., Jeger, M.J. and van Beusichem, M.L. (2000). "Effect of nitrogen supply rate on disease resistance in tomato depends on the pathogen." Plant and Soil 218: 239-247.

Jensen, B. and Munk, L. (1997). "Nitrogen-induced changes in colony density and spore production of *Erysiphe graminis* f sp *hordei* on seedlings of six spring barley cultivars." Plant Pathology 46: 191-202.

Task 1.3 Determining the control efficacy of BCAs and alternative products (EMR, Y1-4)

Work completed.

Task 1.4 Investigate the dynamics of pesticide dissipation under protection for improved determination of the persistence and the appropriate harvest interval (Y2-3, EMR)

Work completed.

Task 1.5 Evaluating a mildew prediction system (Yrs 2-4)

This is reported in Task 7.2.

Objective 2. To develop an IPM system for botrytis through reducing initial inoculum levels in planting material, accurate prediction of risk of flower infection, and the use of BCAs vectored by bees.

Task 2.1: Determine the occurrence of latent *B. cinerea* in commercial strawberry plants at planting (ADAS, CSL, Grower partners Yr. 1-3)

Work completed.

Task 2.2 Evaluate the efficacy of a biocontrol product vectored by bees on control of botrytis fruit rot (ADAS, Agralan Ltd, The Red Beehive Co. Ltd: Years 1-3)

Work completed.

Task 2.3: Validate and use the strawberry botrytis disease forecasting model (BOTEM) in a protected environment (EMR, Yr 1-3)

Work completed.

Objective 3. To establish the importance of alternative hosts as sources of inoculum of *Colletotrichum acutatum* for strawberries in order to develop a sustainable IPM system for blackspot

Task 3.1: Use molecular methods to compare the population of *C. acutatum* from alternative hosts with that from strawberry (EMR, years 1-2)

Work completed.

Task 3.2: Use artificial inoculation to confirm the molecular findings (EMR)

Several research groups in Europe and other parts of the world are currently actively engaged in black spot research. The general conclusions from the large European research projects are that *Colletotrichum acutatum* can infect many different plant species including cherry and apple. Cross-infection among hosts is common although there is some evidence to suggest that one specific group of isolates from strawberry is more aggressive on strawberry than isolates from other hosts. The purpose of this study was to test the pathogenicity of the *Colletotrichum* isolates, obtained from various plant species in England and screened molecularly in Task 3.1, on strawberry.

Tests on fruit (November 2011)

Method

Two mycelial plugs of isolates of *Colletotrichum* spp. from various hosts (Table) were placed onto Potato Dextrose medium (PDA) and the plates incubated at 25^{o}C in the dark for 8 days. A conidial suspension was prepared by flooding the cultures with sterile distilled water (SDW), rubbing with a glass rod and filtering the suspension through two layers of cheese cloth. Spore concentration was determined using a haemocytometer and diluted to 10^5 conidia per ml for each isolate.

Unripe strawberry fruits cv. Premier (8 fruit per isolate per replicate) were surface sterilised in 0.5% sodium hypochlorite and rinsed in SDW and allowed to dry. The fruit was then inoculated with two separate 5 microlitre drops of a conidial suspension of *Colletotrichum.* Four replicates were prepared per isolate and each replicate consisted of eight fruits.

After inoculation the fruits were placed in a moist chamber and incubated at 25^{o}C. Fruits were inspected daily for symptoms. Symptoms of *C. acutatum* were assessed using a scoring system based on lesion size and sporulation (Table 3.2.1).

Results and discussion

The fruit were inoculated on 16 November and assessed for blackspot on 21-29 November. The results are shown in Table 3.2.1. Despite the fruit used in the study being collected from a table top strawberry crop where no botrytis fruit rot was visible and being surface sterilised before inoculation many strawberry fruit developed botrytis rots within 24 hours of inoculation with blackspot. The number of fruit with botrytis steadily increased over the incubation period. All isolates of blackspot caused lesions on the fruit but with the high incidence of botrytis rot it was not possible to score the lesion development.

The tests will be repeated in 2012 in early summer when fruit collected for the study will have a lower risk of botrytis infection.

Table 3.2.1, Pathogenicity of 14 isolates of *Colletotrichum* sp. from various hosts on strawberry fruit cv. Premier Inoculated 16 November, assessed 21-29 November 2011

Isolate number	Host origin	Mean number of fruit with blackspot (max. = 8)		
		21 Nov	25 Nov	29 Nov
1	Strawberry Isle of Wight	0.25	2.25	2.25
3	Weed EMR	0.75	1.5	1.75
4	Willow herb EMR	0.5	0.75	1.5
9	Alder EMR	0.5	1.5	1.5
10	Apple cv. Bramley Chartham	0.25	0.75	1.0
12	Apple cv Bramley Ightham	0	2.0	2.75
13	Primula	0.25	0.5	1.0
14	Strawberry, SC196, EMR	0.25	1.5	2.0
16	Strawberry, SC201, EMR	0	0.5	1.5
17	Apple cv Bramley Hospital Farm	0.25	1.25	1.5
19	Apple cv Gala Rocks Farm, EMR	0	0.5	1.5
20	Apple cv Gala Clockhouse Farm,	0.75	0.75	1.0
21	Bluberry A G Thames	0	0.75	1.0
22	Cherry, Sidnalls Farm, Ulligswick, Herefordshire	0.25	0.5	1.25

Plants

Method

Potted strawberry plants cv. Elsanta in a glasshouse isolation compartment at EMR were inoculated by applying a 5 second spray of a conidial suspension of *Colletotrichum* (prepared as described above) using a hand-held sprayer. The plants were then placed in plastic bags for 48 hours to allow spore germination and infection. The bags were then removed. High humidity in the compartment was maintained using a humidifier. Four replicates were prepared per isolate and each replicate consisted of 1 plant.

After inoculation the plants were inspected weekly for signs of infection. After three months the plants were scored for blackspot lesions using scoring system (Table 3.2.2). Symptomless plant parts were also collected and checked for *Colletotrichum* following treatment with paraquat and incubation at high humidity under UV light.

Table 3.2.2, Pathogenicity of 13 isolates of *Colletotrichum* sp. from various hosts on strawberry plants cv. Elsanta Inoculated 20 December 2010, assessed 15 April, 2011

Isolate number	Host origin	Mean pathogenicity score
1	Strawberry Isle of Wight	1.8
2	Strawberry Suffolk	2.0
3	Weed EMR	1.3
4	Willow herb EMR	2.0
5	Willow herb EMR	1.5
6	Willow herb EMR	1.5
7	Alder EMR	2.3
8	Alder EMR	1.8
9	Alder EMR	2.0
10	Apple cv. Bramley Chartham	1.8
11	Apple cv. Bramley Kent	1.3
12	Apple cv Bramley Ightham	2.3
13	Primula	2.0
15	Uninoculated control	1.3

Score 0 = No lesions,1 = Single lesion on leaf or petiole, 2 = At least two developed lesions
3 = 50% plus of leaves are hooked with black spots, 4 = At least two leaves wilted
5 = All leaves wilted but slightly green, 6 = Dead

Results and discussion

The plants used in the pathogenicity test were mature runners. Black lesions or reddish spots developed on the petioles of most plants inoculated. However, a few lesions were also observed on the uninoculated controls (15 in Table 3.2.2). None of the lesions on the plants were observed to be sporing with *C. acutatum.* Some of the petioles with lesions were subsequently checked for *C. acutatum* using paraquat. Sporing colonies of *C acutatum* were detected. Isolates 7 and 12 had the highest pathogenicity scores in the plant tests. These isolates also were among the highest scoring isolates in the 2010 fruit pathogenicity tests. The plant tests will be repeated in February 2012 using younger runners.

Task 3.3: Evaluation of biofumigants to eliminate *Colletotrichum*-infested debris in soil

In the Hortlink biofumigation project biofumigants to control verticillium on strawberry were investigated. The project identified lavender waste and some brassica products, including Biofence as potential biofumigants. Soil sterilisation is an important part of the integrated approach to control blackspot in strawberry production. The purpose of this study is to evaluate the efficacy of these products against *C. acutatum* in the laboratory based on the protocol developed for *Verticillium dahliae* testing.

Methods

Soil preparation

Approximately 50 L of soil was obtained from the flower bed adjacent to the EMB building and divided among 9 black sacks. The soil was weighed in each sack. Three sacks were left untreated; lavender waste pellets (6.5 g per kg of soil) were added to three and Biofence pellets (1.6 g per kg of soil) added to the final three. All soil in the sacks was well mixed. The untreated and treated soil was then used to part fill each of 9 x 15 kg sterile grey crates. Water was added to each crate of soil sufficient to produce a wet soil without turning to mud.

Colletotrichum inoculum preparation

Strawberry fruits and plant debris, infected with *C. acutatum* was cut up, mixed and 10 g sealed into green mesh bags (wind break green mesh). These were placed in soil in the grey crates, 5 bags per crate, on the soil surface. And more treated or untreated soil added to cover the bags as appropriate. The crates were covered with black plastic to prevent the soil drying out and seal in the biofumigant. The boxes were left to incubate at ambient temperature inside a cool place.

Detection of Colletotrichum

One week after treatment one net bag was removed from each crate and processed as follows. The bag was washed well under running tap water to remove soil. The contents were then chopped up into small pieces and shaken in 200ml sterile water for 30 min. The sterile water / debris mix were then spread on to plates (MS media and DPYA) and allowed to dry slightly before covering. The plates were incubated at 25^{o}C in dark for 5-7 days and then assessed for presence of *Colletotrichum***.** Bags from each crate were sampled after 1 weeks, 3 weeks and 6 weeks and 9 weeks.

Results and discussion

The experiment is currently being assessed.

Task 3.4: Development of simple guidelines for blackspot management

Work completed.

Objective 4: To develop an IPM system for European tarnished plant bug on strawberry using a trap crop, a semiochemical female repellant and tractor mounted vacuuming

Task 4.1. Quantify the relative attractancy of candidate herbaceous flowering plants and cover crops to *L. rugulipennis* (EMR, Yr 1)

Alyssum in strawberry leg rows as a trap crop for *L. rugulipennis* 2011

Methods

The aim of this study was to determine the attractiveness of alyssum to *Lygus rugulipennis* when planted in the leg rows of a strawberry crop. One replicated small plot experiment compared the fauna of alyssum vs. strawberry plants next to the alyssum compared to furthest from the alyssum.

The site was a strawberry plantation (cv. 2nd year Camerillo, 0.75 ha) at Robert Boucher and Son, Newlands Farm, Teynham, Sittingbourne, Kent ME9 9JQ by kind agreement of Hugh Boucher (NGR TQ 963 617). The rows were approximately 134 m long. The tunnel spacing

was 6.5 m and they were in 4 beds per tunnel. The crop was covered when visited on 7 June 2011.

Treatments were 4 x 4; 1 m peat bags of alyssum (15 plug plants per bag) vs. tap samples of strawberry plants (Figure 4.1.1) provided with trickle irrigation.

There were 4 replicates of each or 3 treatments 1. alyssum, 2. strawberry next to alyssum, 3. strawberry far from alyssum. Plots were 4 m long for alyssum or 40 plants for strawberry (Figure 4.1.1). The treatments were in tunnels 3, 7 and 10. The tunnels were marked with yellow tape. The alyssum bags were placed at 26 and 47 hoops in tunnel 3 and 24 and 49 hoops in in tunnel 10.

Figure 4.1.1. Experimental design. Location of plots. White = alyssum sampled, red = strawberry sampled, green = pheromone traps.

The alyssum (*Lobularia maritima*) was pre-sown in a greenhouse in modules by EMR. Seed was obtained by EMR from Ball Colegrave Ltd, Banbury. When plants were planted into new 1 m peat bags *in situ*, 15 plants per bag in 4 groups of 4.

A Stevenson's screen with a data logger temperature and humidity recorder was deployed in the centre of the experimental area for the duration of the experiment.

Sampling and assessments done by EMR staff.

Lygus rugulipennis population monitoring with sex pheromone traps: Two *L. rugulipennis* sex pheromone traps were deployed at the beginning of row 1 and end of row 10 and populations of males checked fortnightly.

Alyssum beat sampling: Each alyssum plot (4 bags per plot) was sampled fortnightly from June to September by sweeping using a white tray. 8 sweeps were done per plot, 2 from each of the bags. The total number of *Lygus rugulipennis* adults and nymphs (recorded separately by instar) were recorded per plot as well as numbers of other species to taxa and species where possible.

Strawberry beat sampling: The 40 strawberry plants adjacent to each alyssum plot were sampled as above. In addition 4 sets of 40 plants in the centre row were sweep sampled.

Results

The alyssum grew well throughout the trials. Very few *L. rugulipennis* adults were captured in the pheromone traps (only 14 over the whole season – peaking in June and July). No adults were found tap sampling in strawberry or alyssum although a total of 1 and 6 nymphs were sampled respectively. 15 *L. pabulinus* were trapped in *pabulinus* pheromone traps towards the end of the season with 24 on strawberry and none on alyssum – so alyssum looks unlikely to be attractive to this capsid species. No WFT or *A. rubi* were trapped in either crop. The alyssum was highly attractive to pollen beetles and flea beetles.

Task 4.2. Evaluate the use of hexyl butyrate as a repellant of *L. rugulipennis* females (EMR, NRI Yrs 1-3)

An additional experiment was done in year 4.

Two different mechanisms have been proposed for the reduction in numbers of *L. rugulipennis* reported from earlier experiments on the use of hexyl butyrate. The first is that the compound is a repellent for all stages of the pest. The second is that the compound causes females to stop producing sex pheromone and thus reduces the number of matings and subsequent population development within the treated areas. In 2008, dispensers were identified that released different rates of hexyl butyrate. These dispensers were used in field experiments in purpose sown weed plots and in a strawberry planting at EMR in 2009. There

was no effect of hexyl butyrate on numbers of *L. rugulipennis* adults close to or c 3 m away from the dispensers at any of the rates used. There was also no difference in proportions of males and females around the dispensers compared to the untreated controls. However, this was late in the season and it is possible that females were not calling for males at this time. In 2010 experiments looked at the effect of hexyl butyrate on response of males to the artificial pheromone lures and virgin females. The first experiment was done in August when populations were high. There were some slight differences in the % males in sweep samples for different dates, mainly with hexyl butyrate as a factor and the wind direction as a factor, but not with the lure as a factor. In the repeated measures analysis there was an overall difference between +/- hexyl butyrate, with a lower % of males when hexyl butyrate was present than when it was absent. A second experiment was done in September however bucket trap catches were low. There were no significant differences between treatments for either bucket trap catches or in the number of adults or the proportion of males in sweep samples.

These experiments in 2011 aimed to determine if hexyl butyrate is a repellent to *L. rugulipennis* and to assess the range of influence of the repellent dispensers.

Methods

Hexyl butyrate dispensers were used in combination with artificial sex pheromone in field experiments to determine the mechanism of reported population reductions. Water filled green bucket traps with green cross veins were baited with the dispensers to assess the effects on *L. rugulipennis*. The aim was to determine if hexyl butyrate reduced the numbers of males caught in pheromone baited traps and thus was repellent to males.

<u>Experiment 1 a</u>

The experiment was done on a second year purpose sown weed field at EMR (plot PR). The species *Matricaria perforata* and *Cheopodium album* had been sown on 29 April 2010 and a high *L. rugulipennis* population had built up in 2010 that may have overwintered in the same field.

There were two treatments:

1. The artificial sex pheromone of *L. rugulipennis*
2. The artificial sex pheromone of *L. rugulipennis* plus a hexyl butyrate dispenser attached adjacent to the pheromone.

The hexyl butyrate dispenser was a colourless sachet loaded with 250 µl of hexyl butyrate. These have a release rate of 18 mg/day at 20°C in the laboratory. The artificial sex pheromone lure was a 1 ml pipette tip loaded with 100 µl of the pheromone with a release rate of approximately 40 µg/day. Lures and dispensers were provided by NRI. A randomised block design was used. There were five replicates of each treatment. Traps were placed 20 m apart and were placed directly on the ground secured with a metal pin. Traps were put out on 18 April 2011 and were checked after 2, 9, 15 and 24 days.

Experiment 1 b

The treatments and experimental design were as in Experiment 1 a except that the traps were spaced at 8 m apart in a flowering weed strip at EMR (plot DM183). Traps were put out on 20 April 2011 checked after 7, 13 and 22 days.

Experiment 1 c

The treatments and experimental design were as in Experiment 1 a except that the traps were spaced at 10 m apart near the edge of a purpose sown weed field at EMR (plot RF). Traps were put out on 20 June 2011 and were checked after 8 and 15 days.

Experiment 1 d

The treatments and experimental design were as in Experiment 1 a except that the traps were spaced at 10 m apart and 5 m from the edge of a purpose sown weed field at EMR (plot RF). Traps were put out on 14 Sep 2011 and were checked after 5, 8 and 14 days.

Experiment 2

The experiment was done on the second year purpose sown weed field at EMR (plot PR) as in Experiment 1 a. The aim was to determine the range of repellent effect of the dispensers. Green bucket traps were used to assess the effects of treatments.

There were four treatments:

1. The artificial sex pheromone of *L. rugulipennis*
2. The artificial sex pheromone of *L. rugulipennis* plus a hexyl butyrate dispenser attached adjacent to the pheromone.
3. The artificial sex pheromone of *L. rugulipennis* plus 6 hexyl butyrate dispensers surrounding the bucket trap (in a hexagon formation) with each dispenser placed 1 m away from the bucket trap, attached on a stake at a height of 40 cm.
4. The artificial sex pheromone of *L. rugulipennis* plus 6 hexyl butyrate dispensers

surrounding the bucket trap (in a hexagon formation) with each dispenser placed 5 m away from the bucket trap, attached on a stake at a height of 40 cm.

A randomised block design was used with five replicates of each treatment. The bucket traps were placed in the centre of 20 m x 20 m grid square with one grid square per replicate (Figure 4.2.1.). Traps were put out on 7 July 2011 and were checked after 5, 7, 12 and 14 days.

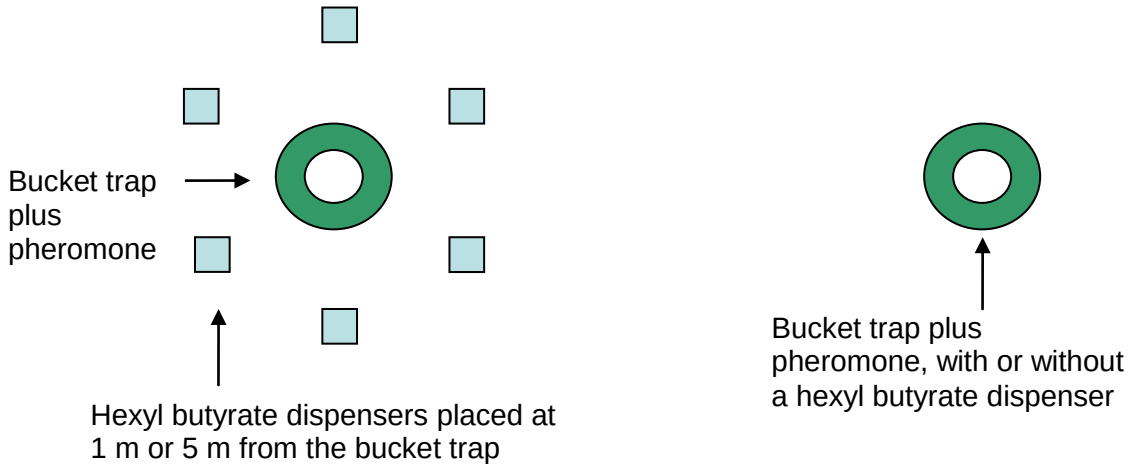


Figure 4.2.1. Experimental design for Experiment 2

Experiment 3

The experiment was done in the second year purpose sown weed fields at EMR (plots PR and RF) as in Experiment 1 a. Green bucket traps were used to assess the effects of treatments.

There were four treatments:

1. The artificial sex pheromone of *L. rugulipennis*
2. The artificial sex pheromone of *L. rugulipennis* plus 4 hexyl butyrate dispensers surrounding the bucket trap, in a 1 m square formation (with the distance from the dispenser to the trap being 0.7 m)
3. The artificial sex pheromone of *L. rugulipennis* plus 4 hexyl butyrate dispensers surrounding the bucket trap, in a 5 m square formation (with the distance from the dispenser to the trap being 3.5 m)
4. The artificial sex pheromone of *L. rugulipennis* plus 4 hexyl butyrate dispensers

surrounding the bucket trap, in a 10 m square formation (with the distance from the dispenser to the trap being 7 m)

A randomised block design was used with five replicates of each treatment. The bucket traps were placed in the centre of 20 m x 20 m grid square with one grid square per replicate (Figure 4.2.2.). Traps were put out on 11 August 2011 and were checked after 5, 7 and 13 days.

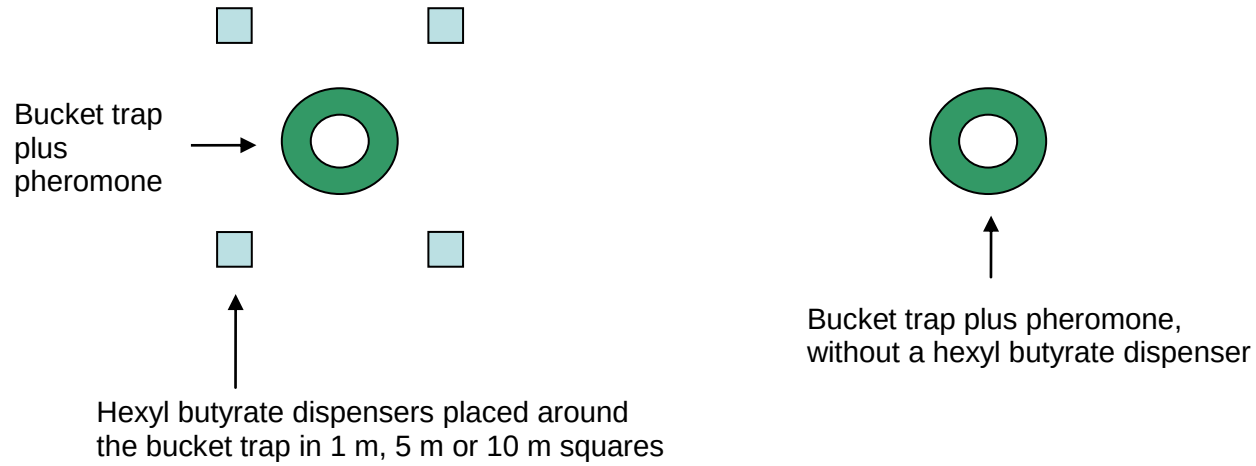


Figure 4.2.2. Experimental design for Experiment 3

Experiment 4

This was set up at a commercial strawberry site under tunnels. The tunnel width was 8m with 5 beds per tunnel. Treatments were either a pheromone trap with 2 hexyl butyrate dispensers placed either side of the trap at a distance of 1 m along the bed, or an untreated control with a pheromone trap alone. This was in a randomised block design with four replicates of each treatment (reducing to 3 as a lure was lost). The traps were spaced at 10 m apart. The bucket traps were placed into a 10 cm hole dug into the bed so as to allow clearance from any spray operations.

Results

Experiments 1 a-d

Bucket trap catches were high in both April and June where the artificial sex pheromone of *L. rugulipennis* was used alone (trap catches were low at the end of the season in September), compared with the sex pheromone plus the addition of hexyl butyrate which caught either no or few capsid bugs (Table 4.2.1.). This indicated that hexyl butyrate was repelling the males. In September only 1 *L. rugulipennis* was caught in the pheromone traps and none in the hexyl butyrate traps although males were present in the field at this time as shown by sweep samples indicating that the adults were not responding to the pheromone at this time in the season. This may explain why the trap catches were low in the previous years experiments.

Table 4.2.1. *Lygus rugulipennis* males caught in green cross vein bucket traps

			Total numbers of males caught per treatment (5 traps)	
Expt No.	**Date experiment was set up in the field, 2011**	**Duration of the experiment**	**Artificial sex pheromone of *L. rugulipennis***	**Hexyl butyrate + artificial sex pheromone of *L. rugulipennis***
Expt 1a	18 April	24 days	129	0
Expt 1b	20 April	22 days	21	0
Expt 1c	20 June	15 days	48	4
Expt 1d	14 September	14 days	1	0

Experiment 2

Trap catches were low in the traps with hexyl butyrate or with hexyl butyrate dispensers placed in a hexagon 1 m away from the trap (Table 4.2.2.). When the hexyl butyrate dispensers were placed at 5 m away from the trap males were caught, with only a 44 % reduction in numbers compared to the control pheromone trap. This indicates a relatively short distance effect.

Table 4.2.2. Numbers of *Lygus rugulipennis* males caught in green cross vein bucket traps placed in the field on 7 July and surrounded by six hexyl butyrate dispensers in a hexagon formation

Treatment	Distance of hexyl butyrate dispensers from the trap (m)	Total number of males caught after 14 days (5 traps)	% Reduction in pest incidence compared to the pheromone alone
Pheromone alone	-	78	0
Pheromone plus hexyl butyrate	0	1	99
Pheromone plus hexyl butyrate	1	1	99
Pheromone plus hexyl butyrate	5	44	44

Experiment 3

Trap catches were low in the traps with hexyl butyrate dispensers placed in a 1 m square around the trap (Table 4.2.3.). However the 5 m and 10 m squares only reduced numbers by 54 % and 21 % respectively compared to the control pheromone trap. This again indicates a relatively short distance effect.

Table 4.2.3. Numbers of *Lygus rugulipennis* males caught in green cross vein bucket traps placed in the field on 11 August and surrounded by four hexyl butyrate dispensers in a square formation

Treatment	Distance between hexyl butyrate dispensers (m)	Distance of hexyl butyrate dispensers from the trap (m)	Total number of males caught after 13 days (5 traps)	% Reduction in pest incidence compared to the pheromone alone
Pheromone alone	-	-	230	0
Pheromone plus hexyl butyrate	1	0.7	12	95
Pheromone plus hexyl butyrate	5	3.5	107	54
Pheromone plus hexyl butyrate	10	7	183	21

Experiment 4

In this experiment, one day after the traps were deployed, a mean of 0.2 and 6.8 males were caught in the hexyl butyrate and control treatments respectively, and by 31 August this had increased to 1.7 and 13.5 (3 reps). When the hexyl butyrate was removed from the area leaving the pheromone traps alone, on 13 September slightly more males were caught in the area which had previously had hexyl butyrate than the area that had no hexyl butyrate with 2.3 and 1 males per trap respectively (3 reps) In September fewer males were caught in the pheromone traps.

Discussion

When used together with the pheromone, the hexyl butyrate dispensers essentially shut down the pheromone traps with no males caught. This effect was seen in experiments from April to June. In September few males were caught in the pheromone traps, perhaps at this time of the season the males in the overwintering form are not attracted to the pheromone. This may explain why there was no effect of hexyl butyrate or the pheromone in previous years when the experiments were done later in the season. The experiments showed that the effect of the hexyl butyrate dispensers was most effective if the dispensers were placed 1-2 m apart, thus this effect is seen only over short distances. If this were to be used practically in a strawberry crop then dispensers would need to be secured every two metres around a plant using a hanging loop, or a different strategy for using the volatile would need to be developed for example using SPLAT.

Task 4.3. Evaluate the use of regularly vacuumed trap crops in an integrated management system in commercial strawberry (EMR, Yrs 2, 3).

Work completed.

Objective 5: To develop an IPM system for aphids which combines the provision of flowering herbage as sources of aphid natural enemies, semiochemical attractants to attract them into strawberry crops, introductions of biocontrol agents and end of season clean up sprays with selective insecticides.

Task 5.1. Evaluate the effectiveness of flowering plants to attract aphid predators and parasitoids (EMR, Yrs 1, 2, 3)

Work completed.

Task 5.2. Evaluate the effectiveness of plant derived semiochemicals to attract aphid predators and parasitoids (EMR/NRI, Yrs 1, 2, 3)

An additional experiment was done in year 4.

Earlier work has demonstrated that various plant volatiles are attractive to a range of insect predators. However, work within this project both in laboratory olfactometry and field trapping experiments has failed to identify an attractive volatile for any predators of strawberry pests, with the exception of hoverflies. In 2010 an experiment was designed to determine if the model predator *Orius laevigatus* could perceive particular volatiles and if behaviour was

affected by them. Despite artificial releases of the predator, trap catches in green bucket traps with cross veins caught few predators, perhaps also due to field temperatures being low. In 2011 a field experiment was done, again with released adult *Orius laevigatus* predators to ensure that high numbers were present at the start of the experiment. Yellow sticky traps were used rather than green bucket traps.

Methods

A field experiment was done in an organic strawberry planting using 3 volatiles that have been shown to be perceived by beneficial insects in other cropping systems: Methyl salicylate, Phenyl ethanol, Farnesene and a blank dispenser (August-September)

A Latin square design was used with four replicates of each treatment. Treatments were:

1. Methyl salicylate
2. Phenyl ethanol
3. Farnesene
4. Blank dispenser

Dispensers were suspended above the yellow sticky trap just above height of the crop canopy and placed at least 10 m apart. Volatile dispensers were high release rate sachets. After setting up the volatiles, *O. laevigatus* adults (BCP Certis, UK) were released into the planting on 18 August 2011. Six tubes of approx.. 500 adults were released between the dispensers in each block (based on the volume of the carrier in the container). The releases were made in adjacent beds to the traps.

Traps were assessed on 25 August and 2 September (and changed after the first assessment). The traps were brought back to the laboratory and numbers of *Orius laevigatus*, anthocorids, lacewings, earwigs, spiders, large sawflies, hoverflies, parasitoids (at the first sample date only), *Lygus rugulipennis* and opiliones were counted. Eight strawberry plants close to each trap were tap sampled on 20 August. In addition four strawberry plants were tapped around ten release plants.

Results and discussion

No Orius laevigatus were found in the tap samples of strawberry plants close to each trap. Low numbers, between 1 and 2 per sample area with a mean of 0.5, were found at the release points. Table 5.2.1. shows the total number of beneficials caught on the yellow sticky

traps on the two sample dates. Although the values per replicate are too low to be analysed statistically, there are slightly more *Orius* sp. on the traps with the methyl salicylate dispensers. This is in agreement with Lee (2010) where positive responses were found from *Orius tristicolor* (White) to methyl salicylate based on sticky traps. Given the numbers of Orius laevigatus released in this experiment, it is doubtful whether methyl salicylate could be used at the current release rate as catches were low. However, methyl salicylate lures are commercially available in the US as PredaLure™ to encourage beneficial insects like ladybirds, lacewings, hoverflies and other beneficial insects.

Table 5.2.1. The total number of beneficials caught on the yellow sticky traps baited with different volatiles in a strawberry crop.

Date	Treatment	Orius sp.	Anthocorids	lacewings	ladybirds	earwigs	spiders	large sawflies	hoverflies	parasitoids	opiliones
25-Aug	Methyl salicylate	8	1	0	12	0	6	10	4	108	19
	Farnesene	2	0	0	11	2	4	5	4	144	16
	Phenyl ethanol	1	0	0	7	0	3	3	3	98	19
	Blank	2	0	0	7	0	3	7	3	117	25
02-Sep	Methyl salicylate	0	0	0	2	1	2	7	1	0	0
	Farnesene	0	1	0	3	1	0	3	1	0	0
	Phenyl ethanol	0	1	0	4	6	0	3	2	0	0
	Blank	1	0	0	2	1	2	2	1	0	0

References

Lee J.C. 2010. Effect of Methyl Salicylate-Based Lures on Beneficial and Pest Arthropods in Strawberry *Environmental Entomology* **39** (2):653-660

Task 5.3. Evaluate the efficacy of post harvest applications of selective insecticides to reduce populations of *C. fragaefolii* in the subsequent season (EMR Yrs 1, 2)

Work completed.

Task 5.4. Evaluate possibility of using the parasitoid *Aphidius eglanteriae* to control *C. fragaefolii* in early season introductions (BCP, EMR, Yrs 1, 2, 3)

Work completed.

Objective 6: To develop a highly attractive 'super' trap for strawberry blossom weevil that combines visual, host plant volatile and sex aggregation pheropmone attractants and to develop methods of using the trap for monitoring and control

Task 6.1. Optimise visual component (EMR, Yr 1)

Work completed.

Task 6.2. Adjust design to minimise the capture of non-target arthropods (EMR, Yrs 1, 2)

Work completed.

Task 6.3. Optimise choice of host plant volatile(s) and blend for synergising the sex aggregation pheromone (EMR, Yrs 1, 2)

Work completed.

Task 6.4. Examine the effect of reducing the amount of Grandlure I in the sex aggregation pheromone lure (EMR, Yr 3)

Work completed.

Task 6.5. Calibrate the super trap for pest monitoring purposes (EMR, Grower partners Yrs 3-5)

Task 6.6. Determine the efficacy of the super trap for control of strawberry blossom weevil by mass trapping (EMR, ADAS, Grower partners Yrs 4-5)

Combining *A. rubi* and *L. rugulipennis* trap

Methods

The objective was to determine whether pheromone traps for *L. rugulipennis* and the strawberry blossom weevil (*Anthonomus rubi*) could be effectively combined into one. We

aimed to determine whether the lures for the two species interacted and which of the trap designs used is effective at catching both species.

The trial was done at Haygrove Ltd, Redbank Farm, Little Marcle Rd, Ledbury, Hereford HR8 2JL by kind agreement of Graham Moor in 'Southfield' (treated) organic plantation. The plantation had moderate levels of blossom weevil, and was planted with cv. Evie 2, an everbearer variety, in March 2010. The experimental plot consisted of 12 tunnels. The tunnels were 7.4 m wide. Each tunnel contained 4 beds (each containing 3 rows of strawberries). The trial was repeated in 2010 and 2011.

The treatments were a factorial comparison of trap design (2 levels), and lure composition (3 levels) (Table 6.6.1). A Latin square design comprising 6 replicates of the 6 treatments was used. Plots were single traps deployed in a square grid, spaced 2 tunnels (= 14.8 m) apart in the leg rows of the Spanish tunnel protected strawberry field.

Table 6.6.1. Treatments

Treatment no.	Factor 1: Trap design	Factor 2 Lure(s)
1. GA	Green cross vane no grid	*A. rubi*
2. GL	Green cross vane no grid	*L. rugulipennis*
3. GLA	Green cross vane no grid	*A. rubi* + *L. rugulipennis*
4. WA	White cross vane with grid	*A. rubi*
5. WL	White cross vane with grid	*L. rugulipennis*
6. WLA	White cross vane with grid	*A. rubi* + *L. rugulipennis*

Traps were Agralan funnel traps with either white or green cross vanes. The white cross vane traps were deployed with a bee excluder grid over the funnel. This is because the white cross vane traps attract non-target insects, such as, honeybees and bumblebees. This was not necessary with the green cross vane traps because they do not attract bees. Lures were either the standard *Anthonomus rubi* sachet containing 100 µl of the normal 1:4:1 blend of Grandlure I: Grandlure 2: lavandulol plus 1 g of the strawberry flower volatile 2, 4-dimethoxybenzene, provided by International Pheromone Systems Ltd. or *L rugulipennis* pipette tips containing 100 µl of the standard blend of hexyl butyrate, (*E*)-2-hexenyl butyrate and (*E*)-4-oxo-2-hexenal (10% in sunflower oil). Plots were single traps

deployed in a square grid, spaced 2 tunnels (= 14.8 m) apart in the leg rows of the Spanish tunnel protected strawberry field.

The traps were stood on the ground and held in place with a wire hoop, and contained water plus a few drops of detergent to break the surface tension. *L. rugulipennis* lures were renewed on each visit.

The grower was requested to avoid spraying the field for the two target pests for as long as possible. A temperature/humidity data logger was deployed in a Stevenson's screen in the field to take half hourly records.

Counts of the number of male *L. rugulipennis* and *Anthonomus rubi* in each trap were made.

Results

Square root transformed data was analysed using a split plot design. Both trap type and lure species were significantly different in the numbers of insects captured ($p<0.001$). The same general pattern was observed in both years, although *A. rubi* numbers were lower in 2011.

More *L. rugulipennis* males were captured in green cross vane traps than white cross vane traps (ANOVA $P<0.001$). More were caught in traps baited with *L. rugulipennis* pheromone than *A. rubi* pheromone baited traps (ANOVA, $P<0.001$). The *A. rubi* lures did not interfere with catches of *L. rugulipennis* or *vice versa*. In a previous HortLINK project HL0184 (PC/SF 276), *L. rugulipennis* was less attracted to white cross vane traps and, in addition, impeded by the grids used as bee excluders (Figure 6.6.1). Also fewer non target insects, including bees, were captured in green cross vane traps.

A. rubi numbers were not affected by cross vane colour. Significantly more were found in the traps baited with *A. rubi* pheromone ($P<0.001$) than the *L. rugulipennis* pheromone.

Any future combined monitoring/mass trap for *L. rugulipennis* and *Anthonomus rubi* should have green cross vane, no grid and both pheromone lures (Figure 6.1.2).

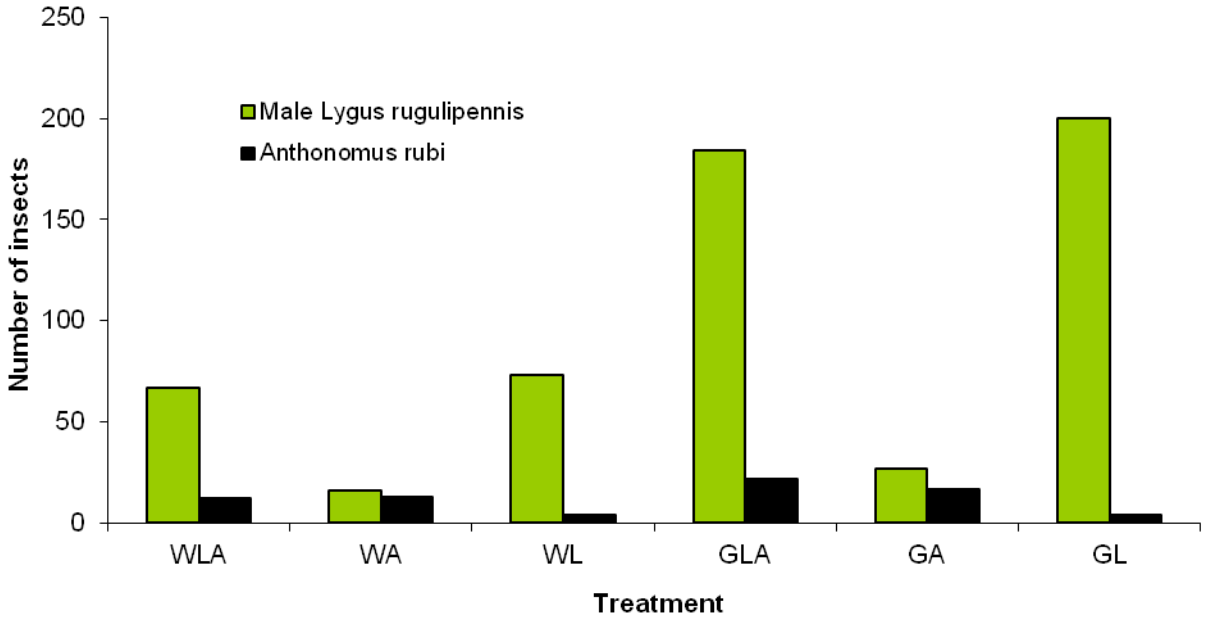


Figure 6.6.1. Mean number of male *L. rugulipennis* and *A rubi* trapped in green (G) or white (W) cross vane traps with *Lygus* (L) and/or *Anthonomus* (A) lures (n=6)

Figure 6.6.2. Recommended monitoring/mass trapping device for *L. rugulipennis* and *A rubi*

Objective 7: To develop and evaluate an Integrated Pest and Disease Management strategy, determining how components interact, its economic performance, effects on other pests, diseases and beneficials and the incidence of pesticide residues.

Task 7.1 - Devise an IPM programme (years 4-5, all partners).

An integrated pest and disease management programme was devised by combining the results from objectives 1-6 on the six specified pests and diseases together with existing established non-chemical control methods. For diseases the strategy comprised three aspects:

- Reduction of initial inoculum
- Development of risk-assessment system for better timing of management practices
- Increased use of BCAs and natural products during flowering.

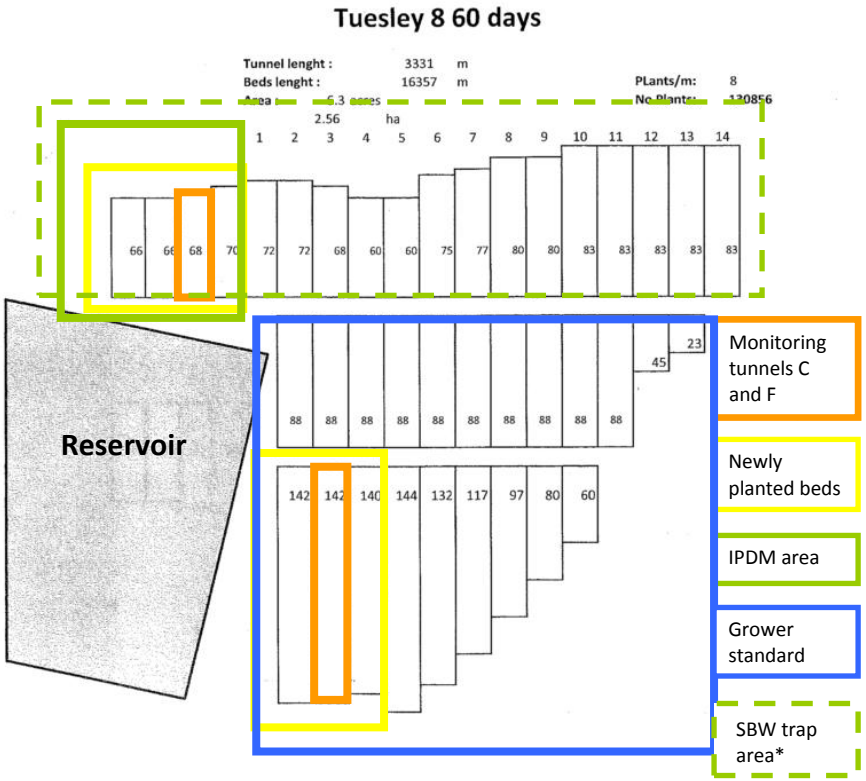
For insect pests an integrated approach using habitat manipulation, semiochemical lures, biocontrol agents together with more species specific control was developed. These systems were evaluated in large commercial plots. Where treatment is required, priority was given to use of natural products and commodity substances, the use of biocontrol (e.g. aphids) or the use of conventional fungicides or insecticides only when a need was identified and the risk of leaving a residue in fruit was assessed as low. Pesticides which have been found to leave detectable residues in fruit, were not, wherever an alternative treatment or chemical was available, not used on fruit.

Task 7.2. - Test IPM in commercial crops (years 4-5; all partners)

7.2.1. Trial sites, summary of monitoring activities and IPDM measures implemented.

The IPM strategy devised in 7.1 was tested in comparison with the standard commercial programme used at the time by the host farmer, at three sites in England, one in Surrey at Tuesley Farm (figure 7.2.1.1.) and two in Kent at Norham Farm and Langdon Manor Farm (Figures 7.2.1.2 and 7.2.1.3). The new strategy and the 'standard commercial programme' control were applied to large plots of protected strawberries. The Tuesley Farm site was planted with var. Elsanta on 28th March 2010, the Norham farm site was planted with var. Sonata on 16 May 2011 and the Langdon Manor Farm site was planted with var. Amesti in early April; the summary of monitoring activities and IPDM measures implemented are shown in tables 7.2.1.1. – 7.2.1.3. for each of the three sites respectively.

Figure 7.2.1.1. Trial plan – Tuesley Farm, Godalming, Surrey, UK



*SBW = Strawberry blossom weevil traps – 36 distributed over ~1 ha

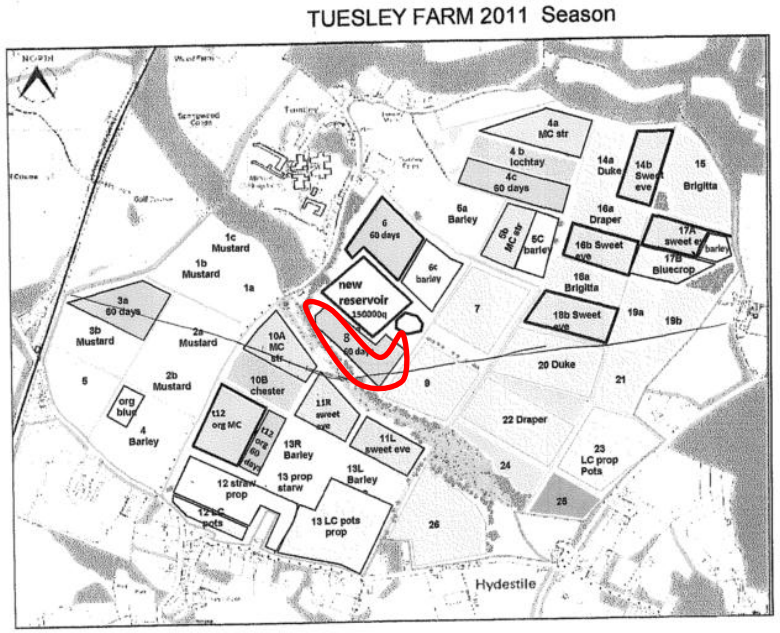
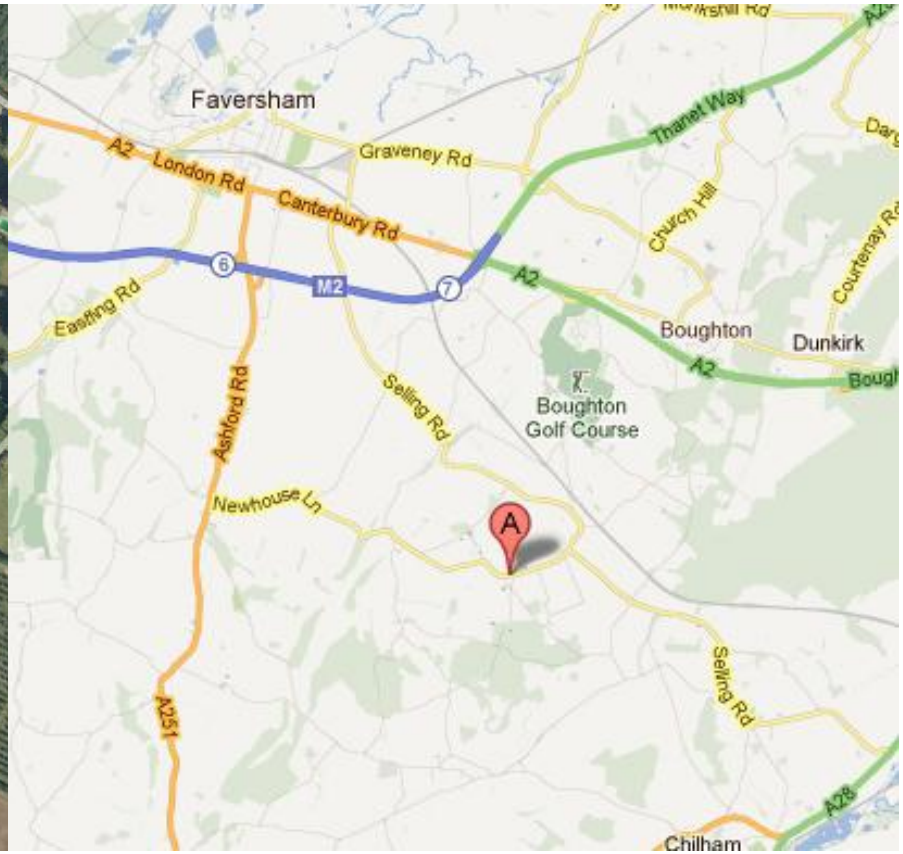


Figure 7.2.1.2. Trial plan – Gaskains Ltd - Norham Farm, Selling, Faversham, Kent, UK



IPDM area

Grower Standard

Figure 7.2.1.3. Trial plan – B.R. Brooks & Son - Langdon Manor Farm, Goodnestone, nr. Faversham, Kent, UK

Trial area
Grower standard (left)
and IPDM (right)

Table 7.2.1.1. Brief descriptions of the Tuesley Farm site, and summary of monitoring activities and IPM measures implemented							
A: Description of each site							
Farm	Location	Planting date	Date covered	Variety	Surrounding plants	Other observations	
Tuesley Farm	Godalming Surrey	28th March 2010	16th May 2010	Elsanta	Blueberries and everbearer strawberries	IPDM tunnel (68m) to SE of GS tunnel reservoir to the N. GS (140m) down slope with reservoir to the E.	
B: summary of monitoring activities and IPM measures implemented							
Growth stage	Monitoring and assessments		Disease		Pests		Other notes
	WC	Advice (protocols)	IDM measures adopted	Grower standard	IPM measures adopted	Grower standard	
			Measures		Measures		
Pre-flowering	4th Apr	Initial visit trial set out	Temperature and humidity loggers introduced for BOTEM and powdery mildew model. Grower downloaded logger twice a week throughout and models run		Strawberry blossom weevil traps introduced 2 per tunnel in to the 18 tunnels in the IPDM block, counts carried out by host grower weekly on 6 traps.	*Phytoseilus persimilis* 100K/ha released	
	11th Apr		Paraat applied for *Phytophthora* through irrigation. ** Nimrod and Signum pre-flowering	Parrat against *Phytophthora* through irrigation			

			applications omitted in error				
	18th Apr and 25th Apr		**Aliette application omitted in error	Aliette 80 WG against *Phytophthora* Stroby against mildew	Aphidsure fragaria 1 tube/200m^2 *Phytoseilus persimilis* 100K/ha and *Amblyseius cucumeris* 1 sachet /2m of bed released	Apollo and Masai applied for spider mite	
Flowering	2nd May	Full P&D assessment	*Audax* bee hives set up allowed to establish without Prestop Mix BOTEM model identified Botrytis risk Serenade ASO applied 10L/ha	Fortress against mildew and Switch against Botrytis.		Pyrethrum against aphid and caterpillar, Thiacloprid against Blossom weevil	
	9th May		PM and Botrytis risk identified by models Serenade ASO applied	Systhane 20EW against mildew and Switch against Botrytis			Tunnel cladding delayed due to planning issues, so delayed the start of the bee dispersed product to the 2nd week of flowering
	16th May	Tunnels clad	Prestop Mix introduced in to hives, 25g replaced twice a week	Topas against mildew and Scala against Botrytis	2nd Aphidsure fragaria release same rate		

			Tunnels clad for 4 weeks, reduced to 8 g for the last week.				
	23rd May	Full P&D assessment, high aphid numbers detected	Powdery mildew model indicated risk potassium bicarbonate applied	Amistar against mildew and Teldor against Botrytis		Calypso against vine weevil	Aphid numbers high in IPDM tunnels
	30th May	Picking starts		Nimrod against mildew and Teldor against Botrytis.	Majestik (maltodextrin and Biomax GP citrus applied for aphid control		
Harvest	6th Jun			Sulphur and Potassium bicarbonate for mildew.	3rd Aphidsure fragaria release	Sluxx applied	Runners removed from all plants.
	13th Jun	Open day and first fruit assessment. Full P&D assessment. Fruit storage assessments started. Residue samples taken	PM risk ID by model, potassium bicarbonate applied	Nimrod and Scala for mildew and Botrytis			Fruit samples stored at either ambient temperature or 4°C before assessment at 3 (ambient only) and 7 days.
	20th Jun – 27th	Second storage assessments started. Residue samples taken	Prestop Mix finished. Potassium bicarbonate sprayed for mildew	Nimrod, sulphur (x2) against Mildew and Teldor (x2) and Rovral against	*Phytosielus persimilis* 30K/ha applied	*Phytosielus persimilis* 30K/ha applied	Aphid numbers reduced. Lots of aphid parasitoid mummies

	Jun			Botrytis		Tracer for Thrips	
	4th Jul	Third fruit storage assessments started, Full P&D assessment	Mildew observed, Potassium bicarbonate and sulphur applied	Sulphur (x2) and Potassium bicarbonate against mildew			Lots of mud splatter on GS fruit
	11th Jul	Full P&D assessment Residue samples taken	Potassium bicarbonate and sulphur applied against mildew	Sulphur and Potassium bicarbonate against mildew			Tunnels de clad alleyways treated with herbicides (Diquat, lenacil and metamitron)
Post-harvest	18th Jul		Potassium bicarbonate and sulphur applied against mildew	Sulphur and Potassium bicarbonate against mildew			
	25th Jul		Fortress applied against mildew	Fortress applied against mildew			Every 2nd plant removed and crop topped
	1st Aug		Alliette for crown rot, Systhane against mildew	Alliette for crown rot, Systhane for mildew	Abamectin and Apollo against tarsonemid and spider mite	Apollo and Dynamec against Spider mite and tarsonemid	Dow shield applied for weed control
	8th Aug – 15th	Full P&D assessment	Corbel against mildew	Corbel against mildew x2			

	Aug						
	22nd Aug			Systhane 20 EW against mildew		Sequel against tarsonemid	
	29th Aug – 5th Sep			Stroby WG, Corbel, Topas, Stroby WG, Systhane 20EW, Topas all against Mildew			
	10th Oct	Autumn P&D assessment	Systhane 20EW against mildew	Systhane 20EW against mildew	Calypso against aphids	Calypso against aphids	

Table 7.2.1.2. Brief descriptions of the Norham Farm site, and summary of monitoring activities and IPM measures implemented											
A: Description of each site											
Farm	Location	Planting date	Date of covered	Variety	Surrounding plants		Other observations				
Gaskains, Norham Farm	Selling, nr Faversham, Kent, UK	16 May 2011	13 June 2011	Sonata	Strawberries to the north and west, raspberries to south, with a hedgerow and arable to the east.		Table top strawberries in coir bags. Site relatively sheltered				
B: summary of monitoring activities and IPM measures implemented											
Growth stage	Monitoring & IPM advice		Disease				Pests				Other notes
	date	Advice (protocols)	IPM measures adopted		Growers		IPM measures adopted		Growers		
			Date	Measures			Date	Measures			
Pre-flowering	25 May	Trial area marked out	25 May	Rovral + Thianosan applied	Rovral + Thianosan + Stroby applied						
	3 June	No mildew seen	1 June	None	Corbel						
	9 June	Full P&D assessment									
	10 June	Trace mildew on young leaf 1/50 leaves	10 June	Routine Aliette for crown rot	Routine Aliette for crown rot Topas						
	16 June	New mildew lesions sporing on several young	16 June	Fortress ?	Fortress				Alpha chlorpyrifos 48 EC		

		leaves. Emailed Grower to spray ASAP							
	22 June	Loggers placed in tunnels. New mildew present on several young leaves. Grower advised to spray				21 June	N. cucumeris (6 boxes Ambsure ABS) and parasitoids (21 Aphidsure frag) supplied by BCP.		
	24 June	Full P&D assessment. Changed all lures.	24 June	Amistar ?	Amistar			Calypso (Thiacloprid)	
Flowering	30 June	New mildew lesions on young leaves. Advised Sulphur spray	30 June	Kindred	Kindred + Robut + Teldor				
	1 July	SBW, sticky stake and Lygus traps checked by grower.	4 July	From 5 July sprays same as growers plot	Switch + Topas				
	6 July	50% of young leaves with new mildew lesions. Full P&D assessment.	13 July	Serenade	Serenade				
	14 July	14/15 new leaves with mildew.	15 July	Potassium bicarbonate +	Potassium bicarbonate +	14 July	Ordered from BCP 21 tubes of		

		SBW, sticky stake and Lygus traps checked by grower.		Kumulus	Kumulus		‘Aphidsure frag’ parasitoids & 21 units of Phytosure (p) 2000		
	21 July	Full P&D assessment.	18 July	Teldor + Topas	Teldor + Topas				
Harvest	25 July	15/16 new leaves with mildew Harvest samples from IPDM and Grower plots	26 July	Nimrod + Teldor	Nimrod + Teldor				
	2 Aug	Full P&D assessment							As the fruit were ripe, plants were‘tickled’ rather than tapped to dislodge pests.
	5 Aug	SBW, sticky stake and Lygus traps checked by grower.							
	8 Aug	New mildew on most young leaves. Young fruit with mildew							

		Harvest samples from IPDM and Grower plots							
	9 Aug	Assessment of waste fruit for pest damage.							
	11 Aug	SBW, sticky stake and Lygus traps checked by grower.							
	16 Aug	Mildew present in IPDM plot very little sporulation. Higher incidence of sporing mildew in grower plot Harvest samples from IPDM and Grower plots.							
	17 Aug	Assessment of waste fruit for pest damage.	17 Aug	Potassium bicarbonate + Sulphur	Potassium bicarbonate + Sulphur				
	18 & 24 Aug	SBW, sticky stake and Lygus traps checked by grower.							
	25 Aug	P&D assessment.							

Post-harvest	1, 9 & 15 Sep	SBW, sticky stake and Lygus traps checked by grower.	15 Sep 23 Sep	Corbel Robut Aliette	Corbel Robut Aliette		3 Sep Dynamec (Abamectin) Apollo 50 SC (Clofentezine)	3 Sep Dynamec (Abamectin) Apollo 50 SC (Clofentezine)	
	13 Oct		13 Oct	Corbel	Corbel		Hallmark with Zeon Technology (Lambda-cyhalothrin)	Hallmark with Zeon Technology (Lambda-cyhalothrin)	
	30 Nov	IPDM and grower plots checked for cleistothecia. Abundant in both plots							

Table 7.2.1.3. Brief descriptions of the Langdon Manor Farm site, and summary of monitoring activities and IPM measures implemented

A: Description of each site

Farm	Location	Planting date	Date covered	Variety	Surrounding plants	Other observations
B R Brooks, Langdon Manor farm	Goodneston e, nr Faversham, Kent, UK	Early April	16 May 2011	Amesti	Strawberries to the north, east and south, with a hedgerow and arable to the west.	Site was exposed and windy.

B: summary of monitoring activities and IPM measures implemented

Growth stage	Monitoring & IPM advice		Disease			Pests			Other notes
	date	Advice (protocols)	IPM measures adopted		Growers	IPM measures adopted		Growers	
			Date	Measures		Date	Measures		
Pre-flowering	11 April	Set up P&D traps							
	14 April	No mildew seen. Botrytis sporing on old leaf debris	14 April	Straw applied	Straw applied				
	18 April	Loggers placed in tunnel							
	21 April	No mildew seen	21 April	None					
	27 April	P&D assessment							Few flowers so only 10

									sampled for thrips, some SBW and Lygus
	28 April	No mildew seen Plants fleece covered	28 April	None		28 April	BCP dispatch 4 boxes of Ambsure (250 per box)(N. cucumeris) and 15 units of Aphidsure (mix of 6 parasitoids)		
	10 May	No mildew seen. P&D assessment. Small number of aphids (M. euphorbiae)	10 May	Fortress + Thianosan	Fortress + Thianosan	10 May		Equity (Chlorpyrifos) against aphids	
	17 May		17 May	Stroby	Stroby	17 May		Brigade (Bifenthrin) against aphids/spider mite	
Flowering	25 May	First flowers. No mildew seen	26 May	Stroby Flowers removed	Stroby Flowers removed	27 May	15 units of Phytosure p 2000 (Phytoseiulus persimilis) and 15 units Aphidsure	26 May – Equity (Chlorpyrifos) against aphids	
	2	P&D assessment							Rabbit

	June	. All lures changed. Low numbers of aphids, some spider mite, some tortrix (Clepsis spectrana).							netting around the polytunnels. No flowers.
	3 June	No mildew seen							
	10 June	No mildew seen Pre-flowering routine spray	10 June	Stroby + Signum	Stroby + Signum	9 June	BCP dispatch 3 boxes Ambsure and 15 units Aphidsure		
	13 June	P&D assessment. Capsid lures changed. Higher numbers of spider mite in the grower standard plot than in the IPDM area.							Plants are starting to flower
	16 June	No mildew seen							
	17 June		17 June	Bees put in IPDM tunnel with Prestop		17 June	Alyssum to be planted out in grow bags.		
	22 June	No mildew seen				21 Jun	BCP dispatch 15 units Phytosure,		

						e	15 units Aphidsure frag, 6 units Orisure (l) (Orius laevigatus)		
			27 June		Topas				
			28 June		Serenade?				
	30 June	First mildew in IPDM 5/35 leaves. P&D assessment.							
			1 July		Amistar				
	6 July	3/30 leaves with new mildew advised weekly Sulphur and/or Pot bicarb	7 July 9 July	Potassium bicarbonate + SW7 Sulphur Flowable	Potassium bicarbonate + SW7? Sulphur Flowable?				
	11 July	P&D assessment							
	14 July	Mildew assessed IPDM and Grower plots	13 July		Amistar	14 July	Ordered from BCP 15 units of Phytosure (p), 15 units of Aphidsure (frag)		
	17 July	3/15 leaves with new mildew	19 July		Topas	16 July		Chess WG (Pymetrozine	

								) & Apollo 50 SC (Clofentezine) against aphids and spider mite	
						19 July		Calypso (Thiacloprid) against aphids and capsids	
Harvest	25 July	8/16 leaves with new mildew. No rots seen in IPDM or Grower tunnel	25 July	Potassium bicarb + Slippa	Potassium bicarb + Slippa?				
	26 July	Harvest samples from IPDM and Grower plots							
	28 July	P&D assessment	28/29 July	Sulphur	Sulphur?				
	2 Aug	Bees removed. Upsetting pickers							
			5 Aug	Potassium bicarb + Slippa	Potassium bicarb + Slippa?				
	9 Aug	P&D assessment							
	11	7/16 leaves with	11		Kindred				

	Aug	new mildew	Aug						
	17 Aug	Harvest samples from IPDM and Grower plots. 9/16 leaves with new mildew	19 Aug	Sulphur	Sulphur?				
	24 Aug	Mildew assessed IPDM and Grower plots. P&D assessment.	26 Aug		Amistar + Teldor	26 Aug		Calypso (Thiacloprid) against capsids	Bug-vaccing on an adjacent plot of Camarillo as proof of concept
	31 Aug	Tap sampling of bug-vacced plots, control plots and plots sprayed with Calypso, alyssum plots and strawberry beds							
			1 Sep	Potassium bicarb + SW7?	Potassium bicarb + SW7?				
			3 Sep	Sulphur?	Sulphur + Nimrod?	3 Sep	Pyrethrum 5 EC (pyrethrins) against capsid – sprayed on the		

							alyssum		
			8 Sep		Kindred + Teldor				
	13 Sep	Harvest samples from IPDM and Grower plots. Tap sampling of bug-vacced plots, control plots and plots sprayed with Calypso, alyssum plots and strawberry beds. Monitoring traps checked.	17 Sep		Topas + Scala				
	27 Sep	Tap sampling of alyssum plots and strawberry beds. Assessment of 3 punnets of fruit to look at % with Lygus damage.							
Post-harvest									

7.2.2. Pest monitoring

The three sites were monitored for a range of pests as appropriate for each species using pheromone traps, tap sampling of the plants and leaf/plant inspections. Different pest species were monitored at each site depending on the date of planting and the crop variety.

Monitoring methods

Lygus rugulipennis and *Lygocoris pabulinus* were monitored using species specific sex pheromone traps per plot placed in the leg rows with a synthetic pheromone supplied by NRI, Chatham, UK. The *L. rugulipennis* traps were green bucket traps with green cross veins (Agralan Ltd., UK). The traps were filled with water and the number of males caught was counted at least every 2 weeks and the water was refreshed. The *Lygocoris pabulinus* traps were sticky stake traps with the lure held under a waterproof cover at the top of the stake. The traps were checked for adult capsids at least every two weeks and the sticky glue was removed and new Oecotak glue (Oecos, UK) was added.

The tortrix moths *Clepsis spectrana*, *Cnephasia longana* and *C. interjectana* were monitored using two species specific sex pheromone traps per plot (International Pheromone Systems (IPS), UK). Traps were checked every two weeks and sticky bases were changed. Pheromone lures were changed every 4-6 weeks.

Strawberry blossom weevils were monitored in the Grower Standard area using two pheromone traps. These were green bucket traps with white cross veins and a plastic grid guard below the cross veins to prevent entry to bees. Pheromones were the commercial pheromone plus PV2 (IPS, UK); these lures last over 100 days. A grid of these traps was used in the IPDM area at a rate of 36 traps per hectare. Traps were checked at least every 2 weeks and water replaced.

Aphids and parasitoid mummies were counted and identified to species on 25-50 plants per plot at each main assessment. Samples were taken to the laboratory and identified where necessary.

Up to fifty plants were also tap sampled over a washing up bowl diameter (for the Norham Farm and Langdon manor Farm sites) or a tray 30 cm x 21 cm (for the Tuesley Farm site); the number of adults and nymphs of *Lygus rugulipennis*, the total number of adult strawberry blossom weevils caught and the number of severed flower buds were recorded. Fifty plants were also assessed for signs of tortrix damage.

At Tuesley Farm thrips were assessed by tap sampling plants over a tray 30 cm x 21 cm and counting the thrips with the a 10-20 x magnification hand lens. At Norham Farm and Langdon Manor Farm thrips were sampled by placing flower samples directly into separate containers with 70% ethanol. Fifty open strawberry flowers from each plot (at both sites) and 50 alyssum growing tips (at Langdon Manor Farm only) were sampled. Thrips in the sample were washed off the flowers and counted under a binocular microscope.

Fifty older trifoliate leaves were sampled into bags and the numbers of motiles and eggs of two-spotted spider mite and phytoseiids were counted under a binocular microscope. Fifty young opened leaves were sampled into bags and the numbers of motiles and eggs of tarsonemid mites and phytoseiids were counted under a binocular microscope.

Biological control agents used in the IPDM programme

The timings for release of biological control agents was dictated by weather and crop stage, and differed slightly from site to site. In general the following protocols were used as a release guide. For aphid control, a commercial mix of six aphid parasitoids was used (BCP, UK). Releases were started 2 weeks after planting with 1 tube per 200 square metres, with 3 releases at 3 week intervals and with further introductions as necessary. To control tarsonemid mite and western flower thrips, *Neoseiulus (Amblyseius) cucumeris* sachets (AMBSURE from BCP, UK) were introduced at 1 sachet per 2 m length of bed before flowering when temperatures were above 12 °C. This was repeated every 6-8 weeks where necessary. As additional control for western flower thrips, *Orius laevigatus* predators (ORISURE from BCP, UK) were introduced at a rate of 0.25 per square metre (if the site had a high risk then this rate

was increased to 0.5 per square metre). This was repeated after 2 weeks where necessary. For control of two-spotted spider mite, *Phytoseiulus persimilis* (Phytosure from BCP, UK) were introduced at 10 per square metre at the first sign of any spider mites. This was repeated every two weeks where necessary.

Tuesley Site

Pest assessments were done from May to August 2011 (Table 7.2.2.1).

Table 7.2.2.1. Total numbers of pest or pest damage per 50 plants at each assessment in the IPDM and Grower Standard (GS) areas at Tuesley Farm in 2011.

Date	Area	Aphids	Parasitoid mummies	Strawberry blossom	Severed flower buds	Thrips (50 flowers)	Tortrix /sawfly	Two-spotted spider mite	Tarsonemid (50 tip
03/05/11	IPDM	3	0	3	0	0	3	0	0
	GS	4	1	3	0	0	1	11	0
25/05/11	IPDM	192	20	0	9	23	1	0	0
	GS	28	4	1	6	44	6	0	0
24/06/11	IPDM	36	120	0	3	77	5	156	136
	GS	0	6	0	1	149	2	16	0
06/07/11	IPDM	5	5	0	1	0	8	659	0
	GS	4	3	-	1	4	9	483	0
15/07/11	IPDM	3	12	-	-	-	9	13	-
	GS	8	3	-	-	-	13	10	0
17/08/11	IPDM	0	0	-	-	-	2	0	3
	GS	0	0	-	-	-	1	2	114

Aphid numbers were higher in the IPDM area than in the Grower Standard on 25 May, and following this high aphid count the number of aphids per 10 plants was counted every three to four days in the IPDM area, with between 13 and 21 aphids recorded per plant. These were mainly strawberry aphid (*Chaetosiphon fragaefolii*)

and potato aphid (*Macrosiphum euphorbiae*). It was decided that due to the increasing numbers an application of Majestik (maltodextrin) and Biomax GP (citrus and coconut extracts) should be applied on 1 June as non insecticidal sprays to assist the released aphid parasitoids in controlling aphids. The number of parasitoid mummies (mainly *Aphidius* spp. and *Praon sp.*) had increased in the IPDM area by 24 June and aphid numbers had declined. By 6 July the numbers of aphids were low in both the IPDM and the grower standard areas.

The release of aphid parasitoids was later than it should have been; BCP Certis advice for the use of Aphisure fragaria suggests the first release should be made as soon as the plants are growing (even if aphids are not seen). The first release at Tuesley was one month after planting on 27 April. Earlier application might have stopped aphid levels building so rapidly in the IPDM tunnels. The high numbers of parasitoid mummies encountered in the visit following the peak aphid counts suggests the aphid parasitoid mix was contributing considerably to the reduction in the aphid population.

The numbers of thrips were higher in the Grower Standard area than the IPDM area. Two-spotted spider mites were generally higher in the IPDM plots than in the Grower Standard, but still only reached on average 13 mites per leaflet in the IPDM area on 6 July and were not found at levels considered to be damaging. Predatory mites and eggs were found at this site by this time. Tarsonemids were present at the Tuesley site, but with no consistent pattern over time.

Strawberry blossom weevil traps were put out on 4 April 2011. A grid of traps was placed in the IPDM area and 2 monitoring traps were placed in the Grower Standard area. Six of the traps in the IPDM area and the 2 traps in the grower control area were monitored weekly until 20 June 2011 by Tuesley farm staff (Table 7.2.2.2.). Strawberry blossom weevil adults were seen in May and the highest numbers of weevils in both the IPDM and Grower Standard were on 9 May 2011, but in general adult numbers and damage was low throughout flowering. Severed buds were apparent by the end of May in both treatment areas.

Table 7.2.2.2. The mean number of strawberry blossom weevil per trap in the IPDM and Grower Standard areas at the Tuesley site.

Date	IPDM area (mean of 6 traps)	Grower area (mean of 2 traps)
11/04/2011	0.0	1.0
18/04/2011	0.5	0.0
25/04/2011	0.5	0.5
02/05/2011	0.2	0.0
09/05/2011	0.7	3.0
16/05/2011	0.2	0.5
23/05/2011	0.2	0.0
30/05/2011	0.0	0.0
06/06/2011	0.0	0.0
13/06/2011	0.0	0.5
20/06/2011	0.0	0.0

There were similar levels of pest damage on samples of Class 2 fruit taken on three occasions at Tuesley farm; 10 % and 6 % had slug damage in the IPDM and Grower Standard plots respectively and no more than 1% of fruit had thrips damage in either treatment.

Norham Farm

The first pest assessment was on the 9 June 2012. Biological control agents were introduced early in the season in the IPDM area. Earwigs were very abundant at this site. Six plastic drinks bottles filled with corrugated card were deployed on table-top legs as artificial refuge traps. These were checked on 24 June and each had over 100 earwigs per trap; earwigs were also present in the tap samples. All table-top posts were painted in oil and were grease banded in both the IPDM and Grower Standard areas to prevent earwig movement into the strawberry crop. On 1 July the traps in the grower area had a mean of 63 earwigs and the traps in the IPDM area had a mean of 45 earwigs.

At this site there few *Lygus rugulipennis* or *Lygocoris pabulinus* bugs throughout the monitoring period. Moth numbers were also low, with no *Clepsis spectrana* caught. Only one *Cnephasia longana* was caught in the IPDM area on 6 July and six *C. interjectana* were caught in both the IPDM and Grower Standard in June and July.

Fifteen strawberry blossom weevil pheromone traps were deployed in the IPDM area in a grid. These traps were checked weekly and the numbers of strawberry blossom weevil adults caught were compared to those caught in the two traps in the Grower Standard area. Strawberry blossom weevils were found in low numbers in both areas between 9 June and 1 September, with 14 in total in the IPDM area and 3 in the Grower Standard area. There were 0.36 and zero severed flower buds per plant on 6 July in the IPDM and Grower Standard areas respectively, and 0.22 and 0.06 severed buds per plant on 21 July.

There were low numbers of aphids in both the IPDM and Grower Standard areas; parasitoids had been released on 24 June and 14 July as part of the IPDM programme.

Thrips numbers were higher in the IPDM area compared to the Grower Standard, however were never higher than 1.5 per flower. *Neoseiulus cucumeris* was introduced to the IPDM area on 24 June.

Two-spotted spider mite numbers were generally lower in the IPDM area compared to the Grower Standard in June and July, increasing in August (Figure 7.2.2.1.). *Phytoseiulus persimilis* was introduced into the IPDM area on 14 July. There were no tarsonemid mites in June, July or August.

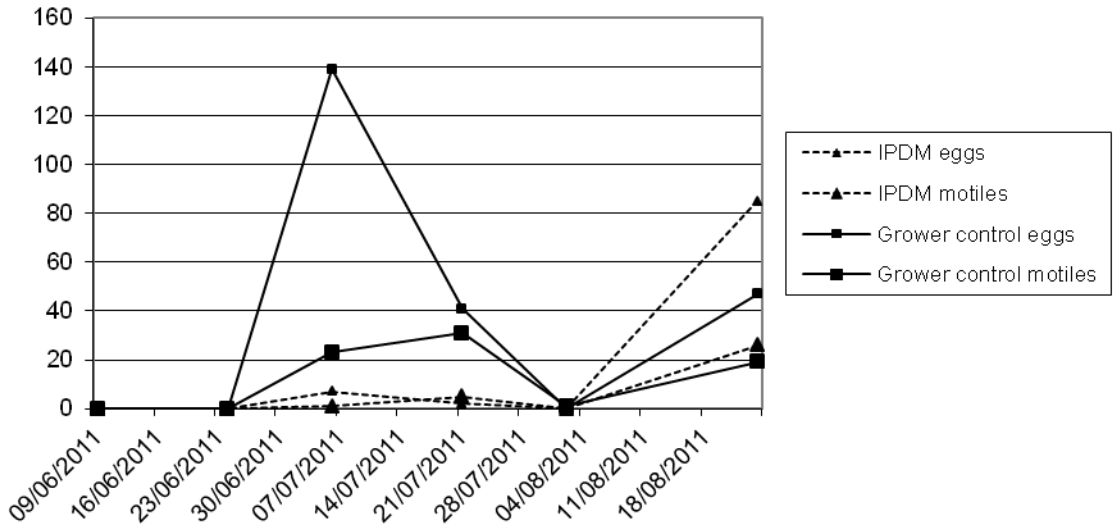


Fig. 7.2.2.1. The number of two-spotted spider mites per 50 strawberry leaves.

The main cause of fruit damage in the waste fruit at harvest was earwig feeding, with 74% of fruit damaged in the IPDM plot and 55% in the Grower Standard area on 26 July, 63% and 24% on 8 August and 49% and 11% on 17 August. In August there was a higher percentage of small fruits in the Grower Standard area than in the IPDM area.

Langdon Manor Farm

Biological control agents were introduced as required in the IPDM plots and monitoring traps were deployed throughout the crop. In addition, an alyssum trap crop (cv Clear Crystal) was sown under cover and the plug plants were planted out in compost bags in mid-June. They were placed in the leg rows and raised to prevent waterlogging using a wooden platform. Two peat bags were placed end to end every 10 m. The bags were drip irrigated using the same line as for the strawberry crop. The plants were flowering well with a low habit (Image 7.2.2.1.) by the time of the peak *Lygus rugulipennis* catch for males on 24 August (Fig. 7.2.2.2.). On this date nymphs were already present on the alyssum trap crop. Forty alyssum plants were tap sampled in total on 31 August, 13 and 27 September at eight areas along the length of a strawberry tunnel. This was compared with the same number of

strawberry plants in the adjacent strawberry bed, in the middle bed and with strawberry plants 5 m along the adjacent bed. On all dates there were more nymphs on the alyssum trap crop than on the strawberry bed (Table 7.2.2.3.). To compare the use of a front mounted bug-vacuum machine with a registered pesticide for capsid control, one tunnel from an adjacent plot of Camarillo was 'bug-vacced' and one tunnel was sprayed with Calypso on 26 August. Two hundred plants from each of the bug-vacced area, the sprayed tunnel and an untreated control tunnel were tap sampled on 31 August and 13 September. Bug-vaccing reduced numbers of *L. rugulipennis* on strawberry to a number comparable with that of the spray of Calypso (Table 7.2.2.4.), i.e. half that of the untreated control. As there were five days between the treatment application and first assessment the number of first instar nymphs may be higher than the other instars as they may have emerged after treatment. The adults are also highly mobile and may move between the tunnels. No *Lygocoris pabulinus* were found at this site.

Image 7.2.2.1. Alyssum trap crop at Langdon Manor Farm, on 13 September 2011.

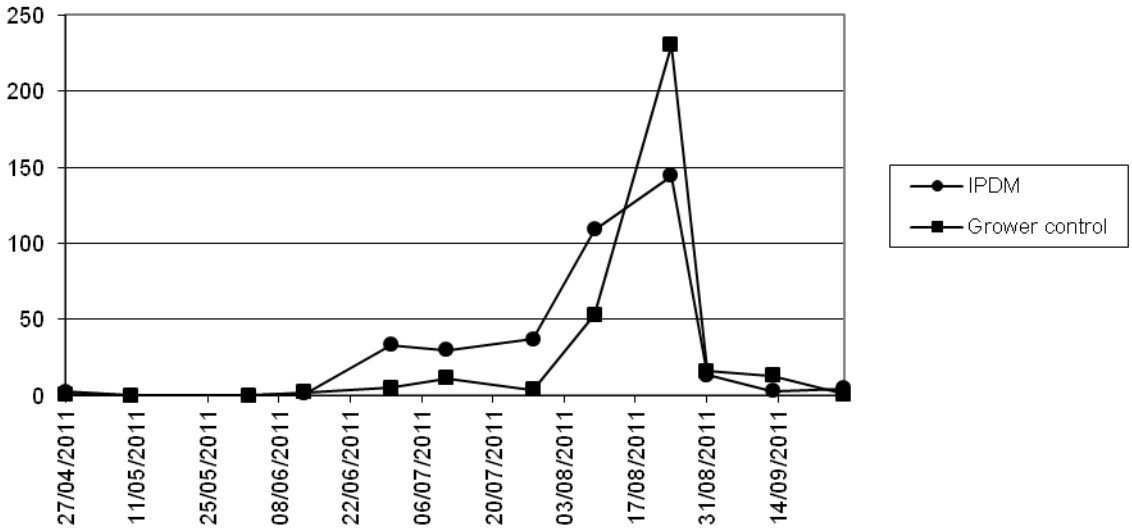


Fig. 7.2.2.2. The mean number of *Lygus rugulipennis* per trap at Langdon Manor Farm in 2011.

Table 7.2.2.3. Total number of *Lygus rugulipennis* nymphs found in tap samples of 40 plants.

Tapping area	31 Aug	13 Sep	27 Sep
Alyssum plants	55	51	40
Strawberry in an adjacent bed parallel to the Alyssum bags	9	6	1
Strawberry in the middle bed parallel to the Alyssum bags	4	0	1
Strawberry in an adjacent bed 5 m along the same row	Not Assessed	3	0

Table 7.2.2.4. The effect of applying the bug-vac machine or a pesticide spray on numbers of *Lygus rugulipennis* nymphs and adults per 200 plants.

Treatment	Date	n1	n2	n3	n4	n5	male	female
Bug vac on 26 August	31-Aug	**9**	**3**	**3**	**1**	**1**	**1**	**2**
	13-Sep	0	1	0	0	1	0	0
Calypso spray on 26 August	31-Aug	**7**	**3**	**6**	**3**	**0**	**1**	**4**
	13-Sep	0	0	0	0	1	0	1
Control	31-Aug	**14**	**13**	**11**	**4**	**5**	**1**	**3**
	13-Sep	1	1	0	0	1	0	1

Moth numbers were low in pheromone moth traps. Nineteen *Clepsis spectrana* were caught in the IPDM area (14 of which were on 2 June) and 3 were caught in the Grower Standard area. Only one *Cnephasia longana* was caught in the Grower Standard area on 11 July. One and 5 *C. interjectana* were caught in the IPDM and Grower Standard areas respectively throughout the season.

A grid of 8 strawberry blossom weevil pheromone traps was deployed in the IPDM area. All of these traps were checked every two weeks and compared to two traps in the Grower Standard area. Strawberry blossom weevils were found in low numbers in both areas between 27 April and 28 July (the date of the last trap catch), with 10 in total in the IPDM area and 6 in the Grower Standard area. Only a few severed buds were seen in each plot.

A commercial mix of 6 aphid parasitoids was released into the IPDM area on 28 April, 27 May, 9 and 22 June. Aphids were mainly *Macrosiphum euphorbiae.* Aphid numbers were 1 or less per plant in the Grower Standard area at all sample dates

apart from on the 13 June when 14 were found per plant. Aphid numbers were 4 or less per plant in the IPDM area with a later peak of 8 per plant on 11 July prior to a population crash (Figure 7.2.2.3.). Any resulting parasitoid mummies were mainly *Aphidius* spp. and *Praon* sp. Parasitoid mummies reached a maximum of 6 per plant in mid-July in both areas.

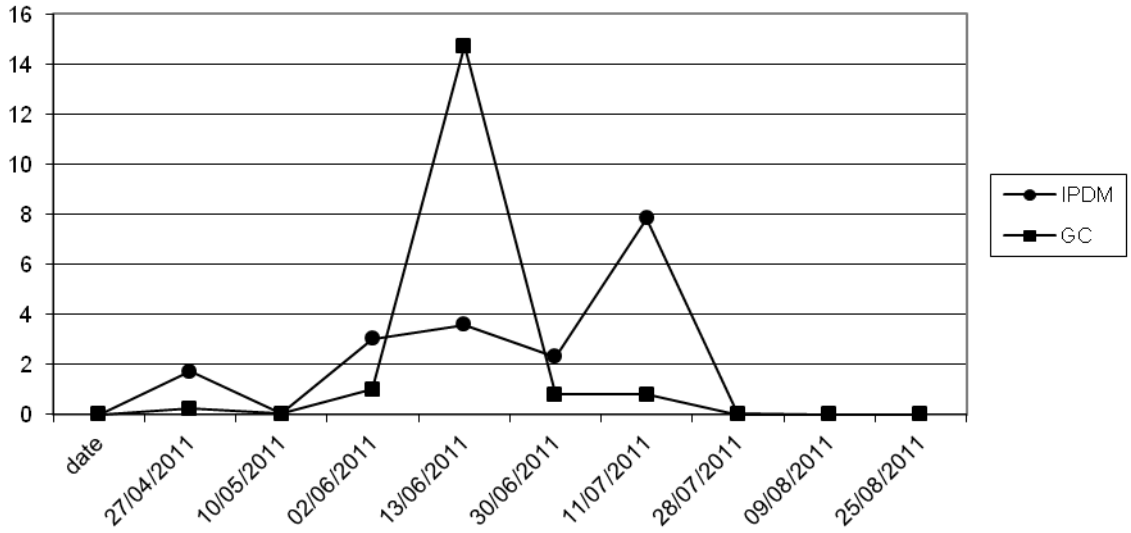


Fig. 7.2.2.3. The mean number of aphids per plant at Langdon Manor Farm.

Neoseiulus cucumeris slow release sachets (Ambsure ABS from BCP, UK) were applied to the IPDM area to allow early establishment of the predator on 28 April and 9 June. However, the number of phytoseiids was higher in the Grower Standard area (Figure 7.2.2.4.). The numbers of thrips increased through July, reaching a peak in August with a similar pattern found in both the IPDM and Grower Standard area.

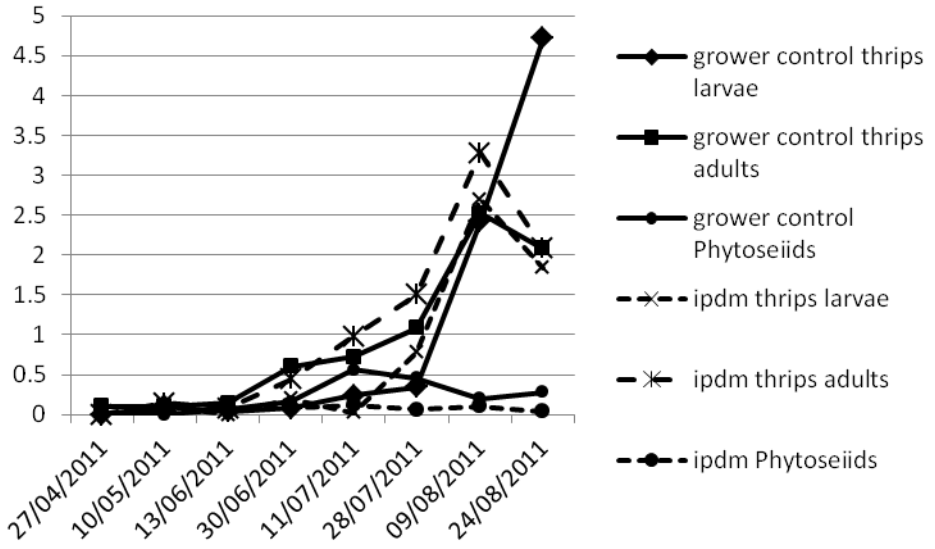


Fig. 7.2.2.4. The number of thrips or phytoseiids per strawberry flower

Phytoseiulus persimilis were introduced on 27 May and 22 June. The number of plants infested with two-spotted spider mite was identical for both treatments and reached a peak on 11 July (with a mean of 156 and 109 motiles, 275 and 187 eggs, per strawberry leaf in the IPDM and Grower Standard areas respectively). Numbers declined by late-July reaching almost zero in early August. The pattern throughout the season was similar for both treatments, although the Grower Standard received sprays of Chess WG and Apollo 50 SC on 16 July which was not requested for the IPDM area. The number of predatory mites was higher in the Grower Standard than the IPDM treatment.

There were 3 tarsonemid adults on 27 April in the IPDM area; there were also 5 phytoseiid adults and 2 eggs in this area at this time.

There was no difference between treatments in waste fruit damage on 26 July, with 19-21% damage, mainly due to earwigs. On 18 August there were only 62 waste fruits from the grower area, 54 of which were over-ripe. There were 527 waste fruits in the IPDM area, half of which were assessed. Of these, a third were over-ripe, 13% had rots, 10% had surface bronzing, 7% had earwig damage and 18% were misshapen (catfaced). The waste fruit picked on 13 September was similar between the IPDM and the grower area, with no more than a 5% difference between the two areas for any damage category. Following the last harvest, all remaining fruit was

picked on lengths of 12 m in total per tunnel (ripe and green fruit). The majority of these fruits were either small or had surface browning. Not many had 'cat-facing' which is generally associated with damage by *L. rugulipennis*.

7.2.3. Management of powdery mildew

Methods and Results

Tuesley farm

Table 7.2.1.1. Gives brief summary of this trial site and management practices applied to the managed and grower plot. Flowering period was from 3rd May to 2nd June, and harvesting ended on 14th July. The farm manager was responsible for downloading weather data and sending the data to Xiangming Xu of EMR to generate forecasts of botrytis and powdery mildew.

From 9th May to 12 October, the managed plot received 11 sprays against powdery mildew (1 x Serenade, 3 x potassium bicarbonate, 3 x [potassium bicarbonate +sulphur], 1 x Fortress, 2 x Systhane, 1 x Corbel). Of these sprays, only the seven non-fungicides were applied in responses to disease forecast or assessments; the other four fungicides were designated as post-harvest spray to clean crops for next season. The grower plot received a total 20 sprays: 1 x Stroby, 2 x Fortress, 4 x Systhane, 1 x Topas, 1 x Amistar, 2 x Nimrod, 1 x [potassium bicarbonate + sulphur], 5 x [Nimrod + sulphur], 2 x Corbel, 1 x [Stroby + Corbel + Topas + Systhane]. Detailed timings of these sprays are given in Appendix 1 b.

Powdery mildew was assessed on 3rd May, 25th May, 24th June, 6th July, 15th July, 18th August, and 18th October. On each assessment date, three youngest fully-unrolled leaves on each of 35 randomly chosen plants were assessed for leaf area with powdery mildew in each treatment tunnel. Powdery mildew was not observed until 6th July (Table 7.2.3.1.). Although the mildew level was higher in the IPDM tunnel than in the grower tunnel, the difference is very small. In autumn, the incidence of leaves with mildew chasmothecia (sexual bodies) was similar between the IPDM (33.3%) and the grower (28.3%) tunnel.

Table 7.2.3.1. Summary of powdery mildew assessment (average % leaf area with mildew) at three trial sites in 2011 where the IPDM strategy was compared with the conventional one. This table excludes non-detailed weekly monitoring carried out at two Kent sites (Langdon Manor Farm and Norham Farm)

Tuesley farm			Langdon Manor Farm			Norham Farm		
Date	IPDM	Grower	Date	IPDM	Grower	Date	IPDM	Grower
06/07	2.14	0.26	14/07	0.7	0.5	14/07	2.6	0.6
15/07	2.22	0.30	24/08	2.6	0.9	16/08	7.6	7.5
17/08	6.01	2.38				30/11	Abundant chasmothecia	
18/10 [chasmothecia]	33.3	28.3						

Norham Farm

Table 7.2.1.2. gives a brief summary of this trial site and management practices applied to the managed and grower plot. Loggers were installed at the site on 18th May and EMR was responsible for downloading weather data and generating forecasts of botrytis and powdery mildew.

The managed plot received 12 sprays against powdery mildew. Of these sprays, eight sprays were applied in responses to mildew assessments or forecasts. The grower plot received a total 20 sprays (Table 7.2.1.2).

Powdery mildew was monitored weekly from 21st April to 16th August on the IPDM tunnel only in order to making spray decisions. Full disease assessment on both IPDM and grower tunnels was made on 14th July and 16th August (Table 7.2.3.1.); on each assessment date, three youngest fully-unrolled leaves on each of 35 randomly chosen plants were assessed for leaf area with powdery mildew in each treatment tunnel. In addition, the amount of chasmothecia was assessed on 30th November. Before mildew lesions were observed, spray timing is primarily determined by the model forecasting; once the mildew level was above the trace level, spray decision was made jointly on the basis of mildew assessment and forecasts.

A trace level of powdery mildew was observed on the second assessment date (10th June) and thereafter increased gradually. On 14th July, about 2.6% leaf area was colonised by mildew for the IPDM plot, compared to 0.6% for the grower tunnel. From mid-July onwards,

nearly all young leaves had fresh mildew lesions. On 16th August, the level of mildew was nearly identical in both tunnels, nearly 8%. There were abundant chasmothecia formed on leaves in both tunnels when assessed on 30th November.

Langdon Manor Farm

Table 7.2.1.3. gives brief summary of this trial site and management practices applied to the managed and grower plot. Loggers were installed at the site on 18th April and EMR was responsible for downloading weather data and generating forecasts of botrytis and powdery mildew.

From 10 May to end of September, the managed plot received 12 sprays against powdery mildew. From flowering onwards these were based on sulphur and potassium bicarbonate. Of these sprays, only 5 sprays were applied in responses to disease forecast or assessments; other sprays were designated as routine pre-flowering sprays or post-harvest spray to clean crops for next season. The grower plot received a total 23 sprays, based on Topas, Kindred, Amistar, Stroby, Sulphur and potassium bicarbonate. Detailed timings of these sprays are given in Table 7.2.3.1.

Powdery mildew was monitored weekly from 3rd April to 24th August on the IPDM tunnel only in order to making spray decisions. Full disease assessment on both IPDM and grower tunnels was made on 14th July and 24th August (Table 7.2.3.1.); on each assessment date, three youngest fully-unrolled leaves on each of 35 randomly chosen plants were assessed for leaf area with powdery mildew in each treatment tunnel. Before mildew lesions were observed, spray timing is primarily determined by the model forecasting; once the mildew level was above the trace level, spray decision was made jointly on the basis of mildew assessment and forecasts.

Powdery mildew was first seen on 30th June and thereafter a moderate level of leaves with fresh lesions was observed weekly. The overall mildew level was very low for both treatments (Table 6.2). On 14th July, only 0.7% and 0.5% leaf area were mildewed for the IPDM and grower treatment, respectively. On 24th August about 2.6% leaf area was mildew for the IPDM treatment, compared to 0.9% mildewed for the grower tunnel.

Discussion

This is the first year trial and thus it is too early to draw any conclusion, especially we are still waiting for spray programme from one trial site and possible carry-over of powdery mildew over the next season. Nevertheless, these preliminary results are encouraging in

demonstrating the comparable control of powdery mildew achieved with the IPDM strategy, but with much reduced input.

7.2.4. Management of Botrytis

Tuesley Farm

Details of the trial site and management practices applied to the managed and grower plots are given in Table 7.2.1.1. The Flowering period was from May 3 to June 2 and harvesting was completed by 14 July. Bees were deployed at this site to deliver the biocontrol agent Prestop Mix (*Gliocladium catenulatum)* for control of Botrytis. The *Audax* bee hives were set up on 3 May at the start of flowering. The hives were placed in the centre of each tunnel raised 1 m above the ground to protect against badger disturbance (Figure 7.2.4.1.). The hives contained the native *Audax* bees supplied by Mike Abel of Agralan and were fitted with an inbuilt dispenser supplied by Biobest, to house the biofungicide product (Figure 7.2.4.2). The Prestop Mix was introduced in to the hives on 19 May having been delayed 2 weeks after the start of flowering due to planning constraints, meaning the tunnels could not be clad till this time. Under the experimental approval status of this product Prestop Mix can only be used in a protected crop.

The Prestop Mix was replaced twice weekly by Tuesley farm staff for 4 weeks. Initially 25 g of the product was introduced each time and any remaining product was removed and weighed to calculate the amount dispersed (Table 7.2.4.1.). On advice from Biobest the amount of Prestop Mix was reduced to 8.5 g for the last 3 introductions to ensure no more than a 2mm covering of the dispenser floor, as research has suggested a thicker layer can disturb the activity of the bees. No evidence of improved activity or dispersal was observed in this final week, however this was towards the end of flowering so there were fewer flowers to vector to.

Bees were observed leaving the hive carrying Prestop Mix and visiting flowers in the IPDM tunnels at site visits during flowering. In total 27 g of the Product was dispersed from the hive.

Prior to the introduction of the Prestop Mix, Botrytis infection risks were identified using Botem on 3 and 16 May and sprays of Serenade ASO were applied in response to the IPDM plots. The use of Prestop Mix finished on 25 June. No other treatments were applied for Botrytis control to the managed plots. In the Grower standard (GS) plot Switch was applied for Botrytis control on 3 May at the start of flowering and again on 16 May. Fungicides for

Botrytis control were then applied at 5-10 day intervals (Appendix 1 b) until 24 June, to give a total of 7 fungicide treatments.

Fruit was harvested for assessment of Botrytis and other rots on 17, 24 and 30 June. At each date a random sample of 8 lots of 50 fruit were collected. Four lots of 50 fruit were placed in module trays in a polythene bag to damp incubate them for 7 days at ambient temperature. Rot incidence was assessed after 3 and 7 days. The other 4 lots of 50 fruit were held in low temperature storage on the farm in punnets for 3 days and then at ambient for 4 days. Rot incidence was assessed after 7 days. Data are presented in Tables 7.2.4.3 1 and 7.2.4.4. The incidence of botrytis was significantly less in the IPD managed tunnels compared to the grower tunnels. Results varied between picks with the greatest difference between IPDM and GS at the second pick when the GS had a greater % of overripe fruit, a greater % visible botrytis and a greater % misshapen fruit in assessments of discarded fruit in the field.

There was concern that this difference could in part be due to the spatial separation of the tunnels, the grower Standard appeared to be wetter than the IPDM tunnels due to the slope of the field with more sheltered humid conditions. An additional assessment was done towards the end of harvest with fruit taken from a tunnel in the same field where the tunnel condition was similar to that in the managed tunnel, but had received standard fungicide treatment. No differences were found between the three tunnels at this stage (Table 7.2.4.4). Penicillium and Mucor rot were also recorded at each of the harvests and were generally at low incidence except for Mucor at the final harvest. There appeared to be very little difference in incidence between the managed and grower plots, in both tunnels very few rots were observed in the crop at harvest in the IPDM tunnel and removal of all waste fruit maintained good hygiene throughout harvest.

The results show that Botrytis following the use of Prestop Mix was no worse than the standard fungicide treatments and could (ignoring the possible microclimate differences between tunnel) be a significantly better treatment than fungicide use. As less than the suggested rate of Prestop Mix (0.7g/day compared to 7.5g/day in glasshouse crops) was dispersed from the hive it would be difficult to conclude that the result was due to the product alone, as there was no untreated control to indicate the Botrytis incidence in the absence of any treatments. The tunnels were chosen in year 1 from those available with newly planted beds and in positions which ensured good spatial separation so the bees could not disperse to the grower tunnel. In year two it is planned to have an additional tunnel and leave this completely untreated for botrytis to have as a control.

Norham Farm

Details of the trial site and management practices applied to the managed and grower plots are given in Table 7.2.1.2. The Flowering period was from end of June to mid-July and harvesting was completed by late August. No bees were deployed at this site to deliver biocontrol agent for control of Botrytis. Pre-flowering routine treatments for Botrytis and blackspot of Rovral + Thianosan were applied on 25 May. Botem risks were identified on 5 June (pre-flowering), 19-27 June and 16-17 July. Treatment with Serenade was advised but not applied. In the grower plot the following were applied for Botrytis and blackspot control – Rovral + Thianosan on 25 May, Switch on 16 June and 4 July, Amistar on 24 June and Teldor on 30 June. From 5 July the same fungicide programme was applied to both the grower and IPDM plots (see appendix 3a, 3b, 3c).

Fruit was harvested for assessment of Botrytis and other rots on 25 July, 8 and 16 August. No Botrytis was observed in the plots at harvest on any of the dates. At each date a random sample of 8 lots of 50 fruit were collected. Four lots of 50 fruit were placed in module trays in a polythene bag to damp incubate them for 7 days at ambient temperature. Rot incidence was assessed after 3 and 7 days. The other 4 lots of 50 fruit were held in low temperature storage on the farm for 3 days and then at ambient for 4 days. Rot incidence was assessed after 3 and 7 days. Data are presented in Tables 7.2.4.5 and 7.2.4.6. No data is presented for cold-stored fruit at the first harvest as the fruit was accidentally marketed. Botrytis was not detected in either the ambient held or cold-stored fruit after 3 days. At the 7 day assessment the incidence of Botrytis in the fruit held in cold store for 3 days was much lower than that held in ambient as expected. There were no differences in Botrytis rot between the fruit from the managed or grower plots. The incidence of Penicillium rot was low in the ambient-held fruit and similar for both the managed and grower plots. The incidence of Mucor rot however increased with later harvesting and the incidence was higher in the fruit from the managed plots compared to that in the grower plots. In the fruit held at ambient, Mucor rot was present after 3 days. Holding the fruit at low temperature delayed the appearance of Mucor but by the final harvest assessment Mucor was present in fruit from the grower plot after 3 days.

These results suggest that for Botrytis rot the treatments in the managed plots were no worse than the standard fungicide programme applied to the grower plots. However, the control of Mucor rot was much worse and this could be an issue during marketing and needs to be addressed. The result for Botrytis control is as expected since virtually the same programme was applied to both plots from mid flowering. The differences in Mucor control are more difficult to explain as the same programme was applied to both.

Brooks site (Landon Manor Farm)

Details of the trial site and management practices applied to the managed and grower plots are given in Table 7.2.1.3. The Flowering period was from the end of May (first flush of flowers were removed to encourage growth) to September and harvesting was completed by the end of September. Honey bees were deployed at this site to deliver the biocontrol agent Prestop Mix for control of Botrytis. The honey bee hives were set up on 17 June at the start of flowering and the Prestop Mix introduced in to the hives on the same day. The Prestop mix (7-15 g) was replaced twice weekly for 6 weeks. Prior to the introduction of the Prestop Mix, Botem risks were identified on 18 May and 5 June. As this was the start of flowering Thianosan and Signum were applied as routine at these times. Further Botem periods were recorded from mid-June to end of June and from mid-July to mid-August. The bees were removed on 2 August as they were upsetting the fruit pickers. During this period no other treatments were applied for Botrytis control in the managed plot. In the grower plot Thianosan and Signum were applied pre-flowering. Fungicides for Botrytis control were then applied at 5-10 intervals (Appendix 2a and 2b) until 13 September, a total of 6 fungicide treatments.

Fruit was harvested for assessment of Botrytis and other rots on 26 July, 17 August and 13 September. No Botrytis was observed in the plots at harvest on any of the dates but rots were present in the discard fruit assessed for pest damage. At each date a random sample of 8 lots of 50 fruit were collected. Four lots of 50 fruit were placed in module trays in a polythene bag to damp incubate them for 7 days at ambient temperature. Rot incidence was assessed after 3 and 7 days. The other 4 lots of 50 fruit were held in low temperature storage on the farm for 3 days and then at ambient for 4 days. Rot incidence was assessed after 7 days. Data are presented in Tables 5 and 6. Botrytis was not detected in either the ambient held or cold-stored fruit after 3 days except in the grower plot fruit at the final harvest. At the 7 day assessment the incidence of Botrytis in the fruit held in cold store for 3 days was lower than that held in ambient as expected. The incidence of Botrytis rot was consistently lower in the fruit from the managed plot compared to that from the grower plot (Tables 7.2.4.7 and 7.2.4.8). The incidence of Penicillium rot was low in the ambient-held and cold-stored fruit and similar for both the managed and grower plots. The incidence of Mucor rot however increased with later harvesting and the incidence was higher in the fruit from the managed plots compared to that in the grower plots. In the fruit held at ambient, Mucor rot was present after 3 days. Holding the fruit at low temperature delayed the appearance of Mucor but by the final harvest assessment Mucor was present in fruit from the both plots after 3 days.

The incidence of botrytis was significantly less in the managed tunnels compared to the grower tunnels. In contrast to the Tuesley site the conditions in the managed and grower tunnels were similar. So it would appear that the result could be due to treatments. These results suggest that the use of Prestop Mix was better than the standard fungicide treatments. The amount of Prestop Mix dispersed from the hive was greater than at the Tuesley site. Problems noted with the bees at this site were: Bees escaping from the sides of the dispenser and not picking up the powder, the majority of bees were observed leaving the hive and flying straight out of the tunnel and returning to the hive from outside the tunnel. There were also other problems such as the bees overheating in the tunnel and dying (50% of the colony) and also being aggressive to the fruit pickers. With both sites where Prestop Mix was used suggesting better control of Botrytis in the managed plots compared to the fungicide plots it may suggest that this could be a genuine result. However, as there was no untreated control to indicate the Botrytis incidence in the absence of any treatments it is difficult to come to any firm conclusions.

Figure 7.2.4.1. Bumble bee hive set up in the centre of the IPDM tunnel – Tuesley Farm 2011

Figure 7.2.4.2. Biobest *Audax* sp. Bumble bee hive with inbuilt dispenser – Tuesley Farm 2011

Table 7.2.4.1. Prestop use at Tuesley Farm in managed plots in 2011

Date	Prestop in tray g	Prestop left in tray g	Amount dispersed g
17 May	25	-	-
19 May	25	20	5
23 May	25	22	3
26 May	25	23	2
30 May	25	22	3
2 June	25	24	1
6 June	25	20	5
9 June	8.5	22	3
13 June	8.5	6	2.5
16 June	8.5	7.5	1
20 June	0	7	1.5
Totals	200.5	173.5	27

Table 7.2.4.2. Prestop use at Langdon Manor Farm in managed plots in 2011

Date	Prestop in tray g	Prestop left in tray g	Amount dispersed g
17 June	7	3.5	3.5
20 June	7	1.6	5.4
23 June	7	0.6	6.4
27 June	7	0	7
30 June	11	0	11
4 July	13	2.4	10.6
7 July	15	3.1	11.9
11 July	15	3.9	11.1
14 July	15	-	-
Totals	97	15.1	66.9

Table 7.2.4.3. Incidence of rots in strawberry cv Elsanta in post-harvest tests following IPDM or grower P&D control programmes and 7 days at ambient temperature in 2011 at Tuesley Farm

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	17 June	3 day	11.5	5.0	0.5	3.5	14.0
		7 day	62.0	29.0	1.5	3.5	68.5
Grower	17 June	3 day	13.0	2.0	0	1.5	14.5
		7 day	70.5	16.0	1.5	4.5	71.0
IPDM	24 June	3 day	19.0	3.5	0	6.0	24.0
		7 day	37.5	11.5	2.0	6.5	41.5
Grower	24 June	3 day	34.0	1.5	0.5	4.0	39.0
		7 day	62.0	14.0	7.0	9.0	66.5
IPDM	30 June	3 day	23.5	3.5	15.0	3.0	36.5
		7 day	56.5	9.0	26.0	5.5	75.5
Grower	30 June	3 day	29.5	2.5	6.5	8.5	36.0
		7 day	67.5	1.0	20.5	6.0	82.5

Table 7.2.4.4. Incidence of rots in strawberry cv Elsanta in post-harvest tests following IPDM or grower P&D control programmes and 3 days at low temperature storage and 4 days at ambient temperature in 2011 at Tuesley Farm

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	17 June	7 day	31.0	5.5	4.0	2.0	69.5
Grower	17 June	7 day	83.3	11.7	5.0	4.2	90.8
IPDM	24 June	7 day	33.0	6.4	5.9	15.3	39.6
Grower	24 June	7 day	41.6	4.9	0	7.4	65.2
IPDM	30 June	7 day	30.5	6.5	9.0	2.0	50.5
Grower	30 June	7 day	20.5	0.5	31.0	8.5	53.0
IPDM	11 July	7 day	60.0	4.5	27.0	14.0	90.0
Grower	11 July	7 day	66.5	5.0	34.0	4.5	91.0
Grower (elsewhere in field)	11 July	7 day	63.5	16.5	35.0	5.0	90.5

Table 7.2.4.5. Incidence of rots in strawberry cv Sonata in post-harvest tests following IPDM or grower P&D control programmes and 7 days at ambient temperature in 2011 at Norham Farm

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	26 July	3 day	0	0	2.0	0	2.0
		7 day	32.5	13.0	7.5	7.0	59.0
Grower	26 July	3 day	0	0	0.5	0	0.5
		7 day	14.0	23.0	5.5	10.5	46.0
IPDM	8 August	3 day	0	0.6	28.3	0	28.3
		7 day	14.2	4.0	67.7	0.8	80.2
Grower	8 August	3 day	0	0	3.2	0	2.9
		7 day	16.1	3.4	35.9	4.8	56.3
IPDM	16 August	3 day	0	0	34.0	0	34.0
		7 day	1.0	0	86.0	0	87.0
Grower	16 August	3 day	0	0	13.0	0	13.0
		7 day	4.0	2.0	70.0	1.5	77.5

Table 7.2.4.6. Incidence of rots in strawberry cv Sonata in post-harvest tests following IPDM or grower P&D control programmes and 3 days at low temperature storage and 4 days at ambient in 2011 at Norham Farm

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	26 July	3 day	ND	ND	ND	ND	ND
		7 day	ND	ND	ND	ND	ND
Grower	26 July	3 day	ND	ND	ND	ND	ND
		7 day	ND	ND	ND	ND	ND
IPDM	8 August	3 day	0	0	0	0	0
		7 day	0.6	0	48.1	0.6	52.2
Grower	8 August	3 day	0	0	0	0	0
		7 day	2.9	0	19.0	3.5	25.9
IPDM	16 August	3 day	0	0	0	0	0
		7 day	0.6	0	39.3	0.3	40.2
Grower	16 August	3 day	0	0	0.3	0	0.3
		7 day	0.3	0	47.0	0	47.0

ND – No data – Cold-stored fruit was marketed

Table 7.2.4.7. Incidence of rots in strawberry cv Amesti in post-harvest tests following IPDM or grower P&D control programmes and 7 days at ambient temperature in 2011 at Langdon Manor Farm

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	26 July	3 day	0	0	3.0	1.0	3.0
		7 day	39.0	10.0	44.0	1.0	80.5
Grower	26 July	3 day	0	0	0	0	0
		7 day	53.5	7.5	11.5	0	62.5
IPDM	17 August	2 day	0	0	0	0	0
		7 day	26.7	3.3	66.7	0	90.8
Grower	17 August	2 day	0	0	0	0	0
		7 day	64.2	5.8	20.8	0	83.7
IPDM	13 September	3 day	0	2.5	32.0	1.0	33.0
		7 day	19.5	8.0	76.5	1.0	97.5
Grower	13 September	3 day	3.0	4.0	9.5	1.0	21.0
		7 day	51.5	15.5	51.5	1.0	97.0

Table 7.2.4.8. Incidence of rots in strawberry cv Amesti in post-harvest tests following IPDM or grower P&D control programmes and 3 days at low temperature storage and 4 days at ambient in 2011 at Langdon Manor Farm

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	26 July	3 day	0	0	0	0	0
		7 day	8.1	0	10.7	3.3	22.1
Grower	26 July	3 day	0.	0	0	0	0
		7 day	4.0	0	2.1	0.8	6.9
IPDM	17 August	2 day	0	0	0.2	0	0.2
		7 day	14.5	0.5	80.7	0	95.3
Grower	17 August	2 day	0	0	0	0	0
		7 day	55.0	0.7	24.0	0	79.6
IPDM	13 September	3 day	0	0	0.2	0	0.2
		7 day	7.0	2.3	65.6	0	78.1
Grower	13 September	3 day	0.6	0	0.4	0	1.0
		7 day	17.6	0.4	15.5	12.7	45.2

7.2.5. Yield of class 1 and 2 fruit, fruit residues and pesticide records

Yield data

Yield of Class 1 and 2 fruit was recorded throughout harvest at the two June bearer sites (Tuesley and Norham farms) and the one Everbearer site (Langdon Manor). Yield was recorded at Tuesley from the 68 m IPDM monitoring tunnel, and the 140 m Grower standard (GS) monitoring tunnel each was 8.5m wide with 5 rows. At Langdon the yield was taken from the 104 m IPDM and 68 m GS monitoring tunnels both 8 m wide with 5 beds. At Norham Farm again yield was taken from the two monitoring tunnels IPDM 163 m and GS 184 m both 8.5 m with 6 table top beds per tunnel, weight of wasted non marketable fruit was also recorded at Norham farm. Table 7.2.5.1. shows the yield scaled up to kg/ha for comparison.

At all sites the proportion of Class 1 fruit was similar following the IPDM and Grower standard programmes at each site. Across both of the treatments, Class 1 comprised a mean 93% at Langdon Manor, but only 70-83% at Tuesley and Norham farms. At Tuesley, splitting and misshapen fruit due to frost early in the season and small fruit size later in the season increased the number of fruit allocated to Class 2. The total yield at Tuesley was 3,155 kg/ha less in the IPDM tunnel and the plants did appear less vigorous this is more likely to be due to the exposed position of this IPDM area than any treatment effect. At Langdon Manor farm and Norham farm the IPDM produced 9,393 kg/ha and 4,962 kg/ha more fruit in total in the IPD managed tunnel than the grower standard respectively suggesting no consistent trend in yield differences for the IPDM program when compared to standard grower practice. At Norham farm the proportion of wasted fruit was 10% higher in the IPDM tunnel and this can be attributed to the levels of earwig damage observed at this site which was greater in the IPDM tunnel, unfortunately records of waste yield was not recorded at the other two sites.

Table 7.2.5.1. Total yield/ha and % Class 1 and 2 fruit over the 2011 harvest for the three farm sites.

	IPDM			Grower Standard		
Tuesley Farm	Class 1	Class 2	Waste	Class 1	Class 2	Waste
Total yield (kg/ha)	15,131	3,521		17,843	3,964	
Mean % per class	81.12	18.88		82.00	18.00	
Langdon Manor Farm						
Total yield (kg/ha)	22,500	1,930		14,200	837.5	
Mean % per class	92.10	7.90		94.43	5.57	
Norham Farm						
Total yield (kg/ha)	22,367	4,646	4,704	21,334	4,117	1,304
Mean % per class	70.52	14.65	14.83	79.74	15.39	4.87

Residue data

Pesticide residue samples were taken on three occasions at Tuesley Farm and 2 occasions each at Langdon Manor and Norham farms. Samples were taken at random from fruit picked from both the IPDM tunnels and Grower standard tunnels and sent to an independent laboratory for residue analysis. All residues were well below the maximum residue levels (MRLs) for the active ingredients of the products applied to each crop (Tables 7.2.5.2 – 7.2.5.4.). Pesticide products and the dates applied at Tuesley and Langdon Manor are given in Appendices 1-3.

Table 7.2.5.2. Residues detected on fruit picked on three occasions at Tuesley Farm, Surrey in 2011 and the maximum residue levels (MRLs) permitted

		Tuesley Farm					
	MRL	Residue levels for IPDM and Grower tunnels (mg/kg)					
	mg/kg	21-Jun		28-Jun		18-Jul	
Chemical		IPDM	Grower	IPDM	Grower	IPDM	Grower
Azoxystrobin	10		0.02		0.015		
Bupirimate	1		0.14		0.22		
Cyprodonil	5		0.04		0.014		
Ethirimol	0.2		0.02				
Fenhexamid	5		0.14		0.73		0.071
Fludioxonil	3		0.05		0.029		
Pyrimethanil	5		0.56		0.41		0.042
Thiacloprid	1		0.02				

At Tuesley Farm no residues were detected above the reporting level at any of the three picks in the IPDM tunnel (Table 7.2.5.2.). In the samples from the grower control a spectrum of insecticide and fungicide actives were reported, but none of these were above their MRLs and corresponded well to the profile of pesticides applied to the crop, showing a reduction in residues as harvest progressed as fewer insecticides were used and sulphur and potassium bicarbonate were used in place of conventional fungicides.

Table 7.2.5.3. Residues detected on fruit picked on two occasions at Langdon Manor Farm, Kent in 2011 and the maximum residue levels (MRLs) permitted

		Langdon Manor Farm			
	MRL	Residue levels for IPDM and Grower tunnels (mg/kg)			
	mg/kg	26-Jul		13-Sep	
Chemical		IPDM	Grower	IPDM	Grower
Azoxystrobin	10		0.28	0.2	0.19
Boscalid	10		0.59		0.049
Bupirimate	1			0.15	0.15
Clofentezine	2		0.34		
Fenhexamid	5			0.82	0.63
Penconazole	0.5		0.024		
Piperonyl butoxide	No MRL			0.15	0.15
Pymetrozine	0.5		0.069		
Thiacloprid	1		0.12	0.081	0.093

At Langdon Manor farm no residues were detected on fruit sampled from the IPDM on the 26th July, whereas the Grower standard again had a spectrum of actives (Table 7.2.5.3.).

At the 13th September pick, however, residues were detected on fruit from the IPDM plots at similar levels to that from the Grower standard plots. None of the chemicals reported from the IPDM tunnel were requested to have been applied according to the IPD program. According to the spray records (Appendix 2b) the products recorded in the IPDM tunnels had been applied to the Grower standard tunnels Amistar (azoxystrobin) and Calypso (thiacloprid) were sprayed on the 26 August, Nimrod (bupirimate) on the 3 September and Teldor (fenhexamid) on the 8 September. It has determined the residues in the IPDM tunnel resulted from unintended pesticide application to the IPDM tunnels. Making conclusions on the IPDM program hard to draw

Table 7.2.5.4. Residues detected on fruit picked on two occasions at Norhams Farm, Kent in 2011 and the maximum residue levels (MRLs) permitted.

		Norham Farm			
	MRL	Residue levels for IPDM and Grower tunnels (mg/kg)			
	mg/kg	26-Jul		16-Aug	
Chemical		IPDM	Grower	IPDM	Grower
Azoxystrobin	10	0.022	0.039		
Bupirimate	1	0.056	0.035	0.025	0.021
Clofentezine	2	0.3	0.13		
Cyprodonil	5	0.093	0.089		0.012
Fenhexamid	5	0.46	0.82	0.93	0.93
Fludioxonil	3	0.13	0.095	0.012	0.014
Iprodione	15	0.52	0.22		0.066
Myclobutanil	1		0.015		
Penconazole	0.5	0.019	0.02		
Thiacloprid	1		0.01		

At Norham Farm, residues were detected on fruit from both the IPDM plots and Grower plots. None of the chemicals reported from the IPDM tunnel were requested to have been applied. The grower spray records show that from the 6th July (half way through flowering) the IPDM tunnel received the same standard spray program as the grower tunnels. Making conclusions on the IPDM program hard to draw

7.2.6. Conclusions

Tuesley Farm

Integrated pest and disease program residue reduction

- The utilisation of the fungicide Serenade ASO (*Bacillus subtilis*) prior to the use of bumble bees to disperse Prestop Mix (*Gliocladium catenulatum*) to the flowering crop for the control of botrytis (under Extrapolated Experimental Approval) resulted in no fungicide use and consequently no residues in the fruit
- Powdery mildew control in the IPDM tunnels was based on a forecasting model utilising in-crop temperature, humidity and disease levels. Potassium bicarbonate was used in response to a risk warning. This reduced the number of otherwise weekly fungicide applications against powdery mildew and hence, together with the use of potassium bicarbonate eliminated residues

- 9 fungicides were applied for Botrytis through establishment flowering and harvest and a further 9 fungicides plus potassium bicarbonate and sulphur were applied to the GS tunnel for powdery mildew. The IPDM tunnel in comparison received 2 applications of Serenade, the use of the bee dispersed Prestop Mix and 7 potassium bicarbonate applications in the same period
- Strawberry blossom weevil numbers in traps and levels of damage were low, awareness of this through monitoring allowed the decision not to apply Calypso (thiacloprid) which was the only insecticide residue present in the GS fruit.
- Aphid numbers at Tuesley farm were greater in the IPDM tunnels in early June but were successfully brought under control through the use of Aphidsure Fragaria (mix of 6 aphid parasitoids) and the use of a maltodextrin spray resulting in no need to apply a conventional insecticide.
- The use of a high rate of *Phytoseilus persimilis* for two spotted spider mite control instead 2 insecticides resulted in slightly higher numbers in the IPDM tunnels compared to the GS but these never reached damaging levels and predatory mites were always visible alongside the pest, this allowed insecticidal control to be delayed until after harvest.
- Other pests were not present in high enough numbers to warrant insecticidal control through flowering and harvest, resulting in no residues on the fruit

<u>Integrated pest and disease program yield</u>

- The use of biological control agents either a formulation for dispersal by bees, or by spray application to flowers, together with the use of potassium bicarbonate in conjunction with powdery mildew risk forecasts resulted in no significant differences overall in yield or in the relative proportions of Class 1 and 2 fruit due to fungal diseases.
- The use of biological control agents as insect predators released into the crop as well as low pest pressure in this season resulted in no real differences in pest damage to fruit with only minimal thrips and slug damage to fruit in both programs, causing no differences overall in yield or in the relative proportions of Class 1 and 2 fruit.

Langdon Manor Farm and Norham Farm

It is hard to draw conclusions on the IPDM program at Norham and Langdon Manor farms as there is uncertainty over the pesticides applied to the IPDM and GS tunnels and therefore the associated effects of the IPDM strategy.

Task 7.3. - Prepare best practice guidelines (year 5; all partners)

APPENDICES

Appendix 1 a. Spray Programme to the IPDM tunnel at Tuesley Farm (April to October 2011)

Date applied	Product	Active ingredient	Product rate / ha
11-Apr	Paraat	Dimethomorph	3 kg
04-May	Serenade ASO	*Bacillus subtilis*	10 L
09-May	Serenade ASO	*Bacillus subtilis*	10 L
25-May	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
31-May	Biomax GP	Citrus and coconut extracts	1.5 L
01-Jun	Majestik	Maltodextrin	25 ml/L
15-Jun	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
19-Jun	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
29-Jun	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
06-Jul	Potassium bicarbonate	Potassium hydrogen carbonate	10 kg
	Sulphur 80%	Sulphur	2 kg
11-Jul	Potassium bicarbonate	Potassium hydrogen carbonate	10 kg
	Sulphur 80%	Sulphur	2 kg
13-Jul	Potassium bicarbonate	Potassium hydrogen carbonate	10kg
	Sulphur 80%	Sulphur	2 kg
16-Jul (inter-row postharvest)	Brough	Diquat	2 L
	Venzar Flowable	Lenacil	3 L
	Goltix Flowable	Metamitron	5 L
27-Jul	Fortress	Quinoxyfen	0.25 L
06-Aug	Aliette	Fosetyl-aluminium	3.75 kg
	Systhane 20EW	Myclobutanil	0.45 L
08-Aug	Abba	Abamectin	0.5 L
	Apollo	Clofentezine	0.4 L
13-Aug	Corbel	Fenpropimorph	1 L
12 Oct	Systhane 20EW	Myclobutanil	0.45 L
	Calypso	Thiacloprid	0.25 L

Appendix 1 b. Spray Programme applied to Grower Standard tunnels at Tuesley Farm (April to October 2011)

Date applied	Product	Active ingredient	Product rate / ha
11-Apr	Paraat	Dimethomorph	3.0 kg
18-Apr	Systhane 20EW	Myclobutanil	0.45 L
27-Apr	Stroby WG	Kresoxim-methyl	0.3
	Apollo 50 SC	Clofentezine	0.4 L
	Masai	Tebufenpyrad	0.75 kg
	Aliette 80 WG	Fosetyl-aluminium	3.75 kg
04-May	Fortress	Quinoxyfen	0.25 L
	Switch	Cyprodinil + Fludioxonil	1 kg
09-May	Pyrethrum 5 EC	Pyrethrins	0.11 L/100 L
10-May	Calypso	Thiacloprid	0.25 L
11-May	Systhane 20EW	Myclobutanil	0.45 L
14-May	Switch	Cyprodinil + Fludioxonil	1 kg
18-May	Topas	Penconazole	0.5 L
	Scala	Pyrimethanil	2 L
25-May	Amistar	Azoxystrobin	1 L
	Teldor	Fenhexamid	1.5 kg
	Calypso	Thiacloprid	0.25 L
31-May	Nimrod	Buprimate	1.4 L
	Teldor	Fenhexamid	1.5 kg
06-Jun	Sluxx	Ferric phosphate	7 kg
07-Jun	Kumulus DF	Sulphur	0.2 kg/100L
	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
17-Jun	Nimrod	Buprimate	1.4 L
	Scala	Pyrimethanil	2 L
21-Jun	Nimrod	Buprimate	1.4 L
	Teldor	Fenhexamid	1.5 kg
24-Jun	Teldor	Fenhexamid	1.5 kg
	Headland sulphur	Sulphur	5 L
	Tracer	Spinosad	0.15 L

27-Jun	Rovral WG	Iprodione	1 kg
	Headland sulphur	Sulphur	3 L
04-Jul	Tracer	Spinosad	0.15 L
	Headland sulphur	Sulphur	3 L
07-Jul	Headland sulphur	Sulphur	0.5 L
	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
11-Jul	Kumulus DF	Sulphur	0.2 kg/100L
	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
13-Jul	Potassium bicarbonate	Potassium hydrogen carbonate	1 kg/100 L
16-Jul (inter-row postharvest)	Reglone	Diquat	2 L
	Venzar Flowable	Lenacil	3 L
	Goltix Flowable	Metamitron	5 L
27-Jul	Fortress	Quinoxyfen	0.25 L
06-Aug	Systhane 20EW	Myclobutanil	0.45 L
	Aliette 80 WG	Fosetyl-aluminium	3.75 kg
	Apollo 50 SC	Clofentezine	0.4 L
	Dynamec	Abamectin	0.5 L
10-Aug	Dow Shield	Clopyralid	0.5 L
13-Aug	Corbel	Fenpropimorph	1 L
20-Aug	Corbel	Fenpropimorph	1 L
27-Aug	Systhane 20EW	Myclobutanil	0.45 L
	Sequel	Fenproximate	2 L
03-Sep	Stroby WG	Kresoxim-methyl	0.3 kg
08-Sep	Corbel	Fenpropimorph	1 L
14-Sep	Topas	Penconazole	0.5 L
15-Sep	Harvest	Glufosinate-ammonium	5 L
21-Sep	Stroby WG	Kresoxim-methyl	0.3 kg
27-Sep	Systhane 20EW	Myclobutanil	0.45 L
04-Oct	Topas	Penconazole	0.5 L
12-Oct	Systhane 20EW	Myclobutanil	0.45 L
	Calypso	Thiacloprid	0.25 L

Appendix 2 a Spray Programme applied to IPDM tunnels in 2011 at Langdon Manor Farm (May to September 2011)

Date applied	Product	Active ingredient	Product rate / ha
10 May	Fortress	quinoxyfen	0.25 L
	Thianosan	thiram	2.0 kg
17 May	Stroby	kresoxim-methyl	0.3 kg
25 May	Stroby	kresoxim-methyl	0.3 kg
10 June	Stroby	kresoxim-methyl	0.3 kg
	Signum	pyraclostrobin +	1.8 kg
		boscalid	
7 July	Potassium bicarbonate + SW7		5.0 kg + 0.5 L
9 July	Sulphur	sulphur	2.0 L
25 July	Potassium bicarbonate +		3.0 kg
	Slippa		1.0 L
28 July	Sulphur	sulphur	1.5 kg
5 August	Potassium bicarbonate +		3.0 kg
	Slippa		1.0 L
19 August	Sulphur	sulphur	1.5 kg
1 September	Potassium bicarbonate + SW7		5.0 kg + 1.0 L
3 September	Sulphur	sulphur	1.5 kg
	Pyrethrum	pyrethrins	2.4 L

Note – fungicides that may be detrimental to the IPDM programme were not applied to the one non-fungicide tunnel, insecticides that may be detrimental to the programme were not applied to the entire IPDM area.

Appendix 2 b Spray Programme applied to grower standard tunnels in 2011 at Langdon Manor Farm (May to September 2011)

Date applied	Product	Active ingredient	Product rate / ha
10-May	Fortress	Quinoxyfen	0.25 L
	Thianosan DG	Thiram	2.0 kg
	Equity	Chlorpyrifos	1.0 L
17-May	Stroby WG	Kresoxim-methyl	0.3 kg
	Brigade 80SC	Bifenthrin	0.3 L
26-May	Stroby	Kresoxim-methyl	0.3 kg
	Equity	Chlorpyrifos	1.0 L
10-Jun	Stroby	Kresoxim-methyl	0.3 kg
	Signum	Pyraclostrobin + Boscalid	1.8 kg
27-Jun	Topas	Penconazole	0.5 L
	Frupica	Mepanipyrim	0.9 L
28-Jun	Serenade	*Bacillus subtilis*	10 L
01-Jul	Amistar	Azoxystrobin	1.0 L
07-Jul	Potassium bicarbonate		5.0 kg
	SW7		0.5 L
09-Jul	Sulphur Flowable	Sulphur	2.0 L
13-Jul	Amistar	Azoxystrobin	1.0 L
	Signum	Pyraclostrobin + Boscalid	1.8 kg
16-Jul	Chess WG	Pymetrozine	0.4 kg
	Apollo	Clofentezine	0.4 L
19-Jul	Topas	Penconazole	0.5 L
	Calypso	Thiacloprid	0.25 L
25-Jul	Potassium bicarbonate		3.0 kg
	Slippa		1.0 L
28-Jul	Sulphur dust	Sulphur	5.0 kg
29-Jul	Headland Sulphur	Sulphur	1.5 kg
05-Aug	Potassium bicarbonate		3.0 kg
	Slippa		1.0 L
11-Aug	Kindred	Meptyldinocap	0.6 L
19-Aug	Sulphur Flowable	Sulphur	1.5 L
26-Aug	Amistar	Azoxystrobin	1.0 L
	Teldor	Fenhexamid	1.5 kg

	Calypso	Thiacloprid	0.25 L
01-Sep	Potassium bicarbonate		5.0 kg
	SW7		0.5 L
03-Sep	Sulphur Flowable	Sulphur	1.5 L
	Nimrod	Bupirimate	1.4 L
	Pyrethrum 5 EC	Pyrethrins	3.0 L
08-Sep	Kindred	Meptyldinocap	0.6 L
	Teldor	Fenhexamid	1.5 kg
17-Sep	Topas	Penconazole	0.5 L
	Scala	Pyrimethanil	2.0 L

Appendix 3 a Spray Programme applied to Grower plots at Norham Farm from 25 May to 4 July in 2011

Date applied	Product	Active ingredient	Product rate / ha
25-May	Rovral WG	iprodione	1.0 kg
25-May	Thianosan DG	thiram	2.0 kg
25-May	Hortiphyte	potassium phosphite	4.0 L
25-May	Stroby WG	kresoxim-methyl	0.3 kg
01-June	Corbel	fenpropimorph	1.0 L
7-June	Harvest		
10-June	Aliette 80 WG	fosetyl-Al	2.5 kg
10-June	Topas	penconazole	0.5 L
16-June	Fortress	quinoxyfen	0.25 L
16-June	Hortiphyte	potassium phosphite	4.0 L
16-June	Switch	cyprodonil + fludioxonil	1.0 kg
16-June	Alpha Chlorpyrifos 48 EC	chlorpyrifos	1.0 L
24-June	Calypso	thiacloprid	0.25 kg
24-June	Amistar	azoxystrobin	1.0 L
24-June	Maxicrop		2.0 L
30-June	Route One Robut 20	myclobutanil	0.45 L
30-June	Kindred	meptyldinocap	0.48 L
30-June	Teldor	fenhexamid	1.0 kg
04-July	Switch	cyprodonil + fludioxonil	1.0 kg

Appendix 3 b Spray Programme applied to IPDM plots at Norham Farm from 25 May to 4 July in 2011

Date applied	Product	Active ingredient	Product rate / ha
25-May	Rovral WG	iprodione	1.0 kg
25-May	Thianosan DG	thiram	2.0 kg
25-May	Hortiphyte	potassium phosphite	4.0 L
7-June	Harvest		

10-June	Aliette 80 WG	fosetyl-Al	2.5 kg
16-June	Hortiphyte	potassium phosphite	4.0 L
24-June	Maxicrop		2.0 L
30-June	Kindred	meptyldinocap	0.48 L

Note – fungicides that may be detrimental to the IPDM programme were not applied to the one non-fungicide tunnel, insecticides that may be detrimental to the programme were not applied to the entire IPDM area.

Appendix 3 c Spray Programme applied to both the Grower and IPDM plots from 5 July to 13 October at Norham Farm in 2011

Date applied	Product	Active ingredient	Product rate / ha
04-July	Topas	penconazole	0.5 L
04-July	Maxicrop		2.0 L
13-July	Serenade ASO	*Bacillus subtilis*	10.0 L
15-July	Potassium Bicarbonate		8.0 kg
15-July	Kumulus DF	sulphur	2.0 kg
18-July	Teldor	fenhexamid	1.0 kg
18-July	Hortiphyte	potassium phosphite	4.0 L
18-July	Topas	penconazole	0.5 L
26-July	Nimrod	bupirimate	1.4 L
26-July	Teldor	fenhexamid	1.0 kg
26-July	Seniphos		3.0 L
05-August	SB Plant Invigorator		1.0 L
17-August	Potassium Bicarbonate		6.0 kg
17-August	Sulphur Flowable	sulphur	1.0 L
03-September	Dynamec	Abamectin	0.5 L
03-September	Apollo 50 SC	Clofentezine	0.4 L
23-September	Robut 20	myclobutanil	0.45 L
23-September	Maxicrop		4.0 L
15-September	Corbel	fenpropimorph	1.0 L
23-September	Aliette 80 WG		
29-September	Harvest	Fosetyl-Al	3.75 kg
13-October	Corbel	fenpropimorph	1.0 L
13-October	Hallmark with Zeon Technology	Lambda-cyhalothrin	0.075 L

SIX MONTHLY REPORT TO HORTICULTURE LINK PROGRAMME MANAGEMENT COMMITTEE

(48 month report due 31 March 2012)

Project Number:		HL0191
Project Title:		Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management
Project Partners:		EMR, ADAS, Fera, NRI, Berry Gardens, Berry World Ltd, TotalBerry, Mack Multiples Division, Marks & Spencer plc, Sainsbury's plc, International Pheromone Systems Ltd, Horticultural Development Company, East Malling Trust for Horticultural Research, East Malling Ltd, Jane & Paul Mansfield Soft Fruit Ltd, Agralan Ltd, Robert Boucher and Son, Red Beehive Company Ltd, Biological Crop Protection Ltd, Koppert UK Ltd
Report Written by:		Scientific consortium members
Project Start/Completion Dates:		1 April 2008 – 31 March 2013
Reporting Period:		42-48 months
Number of Months Since Commencement:		48 months
Date of Last Management Meeting:		15 February 2012
1.	**Project objectives:**	(from project proposal, or other more recently approved planning document)

Objective 1: To develop an IPM system for powdery mildew through reducing initial inoculum levels in planting material, microbial biocontrol, use of natural products, and reducing plant susceptibility to disease through adjustment of N fertiliser application.

Objective 2: To develop an IPM system for botrytis through reducing initial inoculum levels in planting material, accurate prediction of risk of flower infection, and the use of BCAs vectored by bees.

Objective 3: To establish the importance of alternative hosts as sources of inoculum of *Colletotrichum acutatum* for strawberries in order to develop a sustainable IPM system for blackspot.

Objective 4: To develop an IPM system for European tarnished plant bug on strawberry using a trap crop, a semiochemical female repellant and tractor mounted vacuuming.

Objective 5: To develop an IPM system for aphids which combines the provision of flowering herbage as sources of aphid natural enemies, semiochemical attractants to attract them into strawberry crops, introductions of biocontrol agents and end of season clean up sprays with selective insecticides.

Objective 6: To develop a highly attractive 'super' trap for strawberry blossom weevil that combines visual, host plant volatile and sex aggregation pheromone attractants and to develop methods of using the trap for monitoring and control.

Objective 7: To develop and evaluate an Integrated Pest and Disease Management programme for strawberries, determining how components interact, economic performance, effects on other pests, diseases and beneficials and the incidence of pesticide residues.

2.	**Table showing overview of progress against milestones for project as a whole**	(from project proposal, or other more recently approved planning document)

Primary milestones

Milestone	Target month	Title	Achieved
P3.1	11	Blackspot isolates obtained for molecular analysis.	Y
P5.2.1	12	Olfactometry choice test experiments completed and suitable dispensers for methyl salicylate plus one other plant volatile to attract aphid natural enemies developed.	Y
P6.1	12	Visual component of blossom weevil super trap optimised.	Y

P5.4.1	12	Lab culturing method for *Aphidius eglanteriae* developed.	Y
P5.1.1	12	First year experiment to evaluate the effectiveness of flowering plants to attract aphid predators and parasitoids completed.	Y
P5.3.1	14	First year trial evaluating the efficacy of post harvest aphicide treatment completed.	Y
P2.2	22	Validation of the Botem model for protected crop completed.	Y
P1.4	24	Efficacy of Serenade against mildew determined.	Y
P2.4	24	Suitability of bees for dispersing BCAs evaluated.	Y
P4.2.1	24	Feasibility of use of hexyl butyrate as a repellant of *L. rugulipennis* females determined.	Y
P5.4.2	24	Preliminary biocontrol trials with *Aphidius eglanteriae* completed	Y
P6.3	24	Optimum choice of host plant volatile(s) and blend for synergising the sex aggregation pheromone of blossom weevil established.	Y
P3.2	29	Population structure of blackspot determined.	Y
P1.6	33	Fungicide dissipation dynamics determined.	Y
P2.5	33	Model-based control strategies evaluated for botrytis.	Y
P3.4	36	An overall risk assessment scheme developed for blackspot.	Y
P4.3	36	System for regularly vacuuming trap crops for control of European tarnished plant bug developed.	Y
P5.4.3	36	Feasibility of using *Aphidius eglanteriae* as a biocontrol agent for strawberry aphid determined and release methods and rates for testing in the IPM trials in years 4 and 5 decided.	Y
P7.1	36	IPDM programme for testing in final two years of the project established and sites for conduct identified.	Y
P2.7	43	Efficacy of bee-vectored BCA against botrytis determined.	Y
P3.5	43	Possibility of eliminating blackspot inoculum using biofumigation determined.	N
P1.8	48	Effects of nitrogen on mildew susceptibility determined.	Y

P1.9	48	Mildew control strategy (ies) devised.	Y
P1.10	48	Selected products against mildew evaluated.	Y
P7.2.1	48	First years experiments evaluating IPDM programme in commercial crops completed. Changes to the programme decided.	Y
P6.5	60	Blossom weevil super trap calibrated for pest monitoring purposes.	
P6.6	60	Efficacy of the super trap for control of strawberry blossom weevil by mass trapping quantified.	
P7.2.2	60	Second years experiments evaluating IPDM programme in commercial crops completed. Programme finalised and economic appraisal completed.	
P7.3	60	Best practice guidelines prepared.	

Secondary milestones

Milestone	Target month	Title	Achieved
S2.1	1	Site selected for botrytis.	Y
S1.1	2	Products selected for trial.	Y
S1.2	11	Site selected for mildew risk trial.	Y
S1.3	20	Mildew risk system coded as a computer programme with Botem.	Y
S2.3	24	Incidence of botrytis on planting materials determined	Y
S5.1.2	24	Second year experiment to evaluate the effectiveness of flowering plants to attract aphid predators and parasitoids completed.	Y
S5.2.2	24	Field experiment testing the release rate of each plant volatile to attract aphid natural enemies completed and the most effective lure identified. (see below)	Part Y
S5.3.2	24	Second year trial evaluating the efficacy of post harvest aphicide treatment completed, feasibility determined and best treatment identified.	Y
S6.2	24	Design of super trap for blossom weevil adjusted to minimise the capture of non-target arthropods.	Y
S3.3	29	Cross-inoculation of selected blackspot isolates completed.	Part Y

S1.5	33	Alternative products selected for the larger trial against mildew.	Y
S2.6	36	Methods for reducing botrytis in planting materials determined.	
S1.7	36	Methods for reducing mildew in planting materials determined.	Y
S4.2.2	36	System for using hexyl butyrate as a repellant of *L. rugulipennis* females developed ready for testing in IPM programme in final 2 years.	N
S5.1.3	36	Third year experiment to evaluate the effectiveness of flowering plants to attract aphid predators and parasitoids completed	Y
S5.2.3	36	Replicated field experiments evaluating the efficacy of the most effective dispenser of the host volatiles deployed in lattice through the crop completed and the feasibility of using them for attracting aphid natural enemies determined.	N
S6.4	36	The effect of reducing the amount of Grandlure I in the sex aggregation pheromone lure for blossom weevil established and optimum amount established.	N

3.	**Milestones for the six month period:**	(from project proposal, or other more recently approved planning document)	
P2.7	43	Efficacy of bee-vectored BCA against botrytis determined.	Y
P3.5	43	Possibility of eliminating blackspot inoculum using biofumigation determined.	
P1.8	48	Effects of nitrogen on mildew susceptibility determined.	
P1.9	48	Mildew control strategy (ies) devised.	
P1.10	48	Selected products against mildew evaluated.	
P7.2.1	48	First years experiments evaluating IPDM programme in commercial crops completed. Changes to the programme decided.	Y

4.	**Research report:**	(concise account including comments on whether targets are being met)

Strawberry powdery mildew: A further two batches of cv. Sonata plants were obtained from a local farmer where there is a historical problem of powdery mildew. These batches of plants were potted up and maintained in isolation (CE cabinets) to observed powdery mildew development. None of plants had developed mildew lesions within 3 weeks. This was also consistent with the slow build-up of epidemics in the field plantation

of the same plant materials. Three batches of leaves (with mildew, without mildew but from mildew-infected plants, and healthy leaves from healthy plants) were sent to Fera to validate the molecular primer developed for powdery mildew.

A further trial was conducted to investigate the high nitrogen input during fruiting period on the susceptibility of strawberry leaves to powdery mildew. The experimental design was exactly the same as the last year. The experiment was completed. Data from three replicate trials will be statistically analysed to determine the effects of nitrogen on mildew susceptibility.

European tarnished plant bug:

Use of hexyl butyrate as a repellent: In April and in June *L. rugulipennis* were caught in bucket traps containing the sex pheromone alone, but none were trapped where hexyl butyrate dispensers were included indicating that hexyl butyrate was repelling the males. In September only 1 *L. rugulipennis* was caught in the pheromone traps and none in the hexyl butyrate traps although males were present in the field at this time indicating that the adults were not responding to the pheromone at this time in the season. This may explain why trap catches were low in the previous years' experiments. In replicated experiments designed to test the range of influence of the hexyl butyrate dispensers using grids of dispensers at 1m spacing no *L. rugulipennis* males were caught in pheromone traps whereas at larger spacings they were indicating a relatively short distance effect. In another experiment at a commercial site treatments were either a pheromone trap with 2 hexyl butyrate dispensers placed 1 m away along the bed, or an untreated control with a pheromone trap alone. One day after traps were deployed a mean of 6.8 and 0.2 males were caught in the hexyl butyrate and control treatments respectively, and by 31 August this increased to 13.5 and 1.66.

IPDM programme: The new control approaches that have been developed for the main pests and diseases of strawberry in the first 3 years of the project have been combined with existing approaches into a new Integrated Pest and Disease Management programme which will reduce pesticide use and greatly reduce the incidence of pesticide residues. This programme was evaluated on a commercial scale on 3 farms in 2011 and 2012, in comparison with the growers existing standard practices.

IPDM trials were conducted at three sites: two in Kent and one in Surrey. Grey mould on June-bearers in Kent was not chemically controlled based on previously-obtained results, whereas grey mould on Kent ever-bearers and Surrey June-bearers was controlled with a honey bee and bumble bee dispersed biocontrol agent respectively. At the Kent sites, biofungicides were used with the timing depending on the BOTEM model predictions. Powdery mildew control at three sites was all initially determined by the

model prediction with more weight given to disease severity once mildew was present in the plantation. Fruit were picked from both conventional and IPDM treatments and assessed for post-harvest fungal infection and the level of pesticide residues.

In Kent, two experiments were set up, one on June bearers and one on everbearers. Pests were monitored throughout the growing season in both experiments and data are presented in the annual report. On 25 May an experiment was set up on June-bearers cv. Sonata, planted on 16 May in coir bags and grown on table tops. Biological control agents were introduced early in the season in the IPDM plot. The main cause of fruit damage at harvest was earwig feeding, with 74% of fruit damaged in the IPDM plot and 55% in the grower control area on 26 July 63%, and 24% on 8 August and 49% and 11% on 17 August. On 11 April an experiment was set up on ever-bearer strawberries var. Driscoll Amesti, planted in early April. Biological control agents were introduced as required in the IPDM plot. The peak catch for *Lygus rugulipennis* males was on 9 August, and by 31 August nymphs were present, with more nymphs on the alyssum trap crop than on the strawberry bed. Bug-vaccing reduced numbers of *L. rugulipennis* on the strawberry plants. Marketable fruit was higher by punnet volume in the IPDM plot than in the grower control area.

The Surrey June-bearer experiment was set up on 4 April on cv. Elsanta planted 28 March into newly formed polythene covered raised soil beds. Strawberry blossom weevil traps and biological control agents were introduced into the IPDM tunnels early in the season. Strawberry blossom weevil (*Anthonumus rubi*) numbers and damage were low throughout flowering in both the IPDM and Grower Standard tunnels. Aphid numbers, predominantly strawberry (*Chaetosiphon fragaefolii*) and potato aphid (*Macrosiphum euphorbiae*) peaked in early May and were initially more prevalent in the IPDM tunnel (in which Aphidsure fragaria mix was used), but then reduced by parasitism.

Effective powdery mildew control in the IPDM tunnel utilised temperature and humidity data and field disease assessments, with the model dictating the need for application of potassium bicarbonate.

The biofungicide Prestop Mix (*Gliocladium catenulatum*) was first introduced to the *Audax* bumble bee hive in the IPDM tunnel on 16 May. The bees dispersed the product throughout flowering. There was no significant difference between the tunnels in the proportion of fruit showing botrytis in the field. The proportion of class one fruit harvested was also the same (IPDM 80%, Grower 79%).

Fruit samples were taken and incubated at either ambient temperature or at 4 ºC for 3 days followed by ambient for 3 days. After 6 days storage, there was more marketable fruit from the IPDM than the Grower tunnel (47% compared with 30%) and less botrytis

(31% compared to 49%). There was less botrytis in the samples initially cold stored for 3 days compared with those stored throughout under ambient conditions (40% compared with 60%) and more marketable fruit (39% compared with 32%). Fruit was sampled in June and July for pesticide residue testing, with active ingredients detected only in samples from the Grower Standard.

5.	**Project changes:**	(proposed or agreed with the LINK programme, and including any changes to expected profile of grant claims)

None

6.	**Publications and technology transfer outputs:**	(including public presentations/talks given. Indicate additions since last report by use of bold type)

Technology transfer activities

Publications

7.	**Exploitation plans:**	(give an update on perceived exploitation opportunities and future plans.)

Most of the exploitation of the project by growers will come at the end of the project. However, the use of autumn sprays against aphids the following season has been very successful and could be implemented now. SBW and Lygus traps will be available as monitoring tools for the pests in strawberry plantations from a commercial supplier for the 2012 season.