Project title:	Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management
Project number:	HL0191, SF 094
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The following are members of the Consortium for LINK project HL 0191:

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DISCLAIMER

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

Novel pest and disease control techniques can be incorporated into a new IPDM programme to reduce pesticide use and subsequent incidence of pesticide residues, without a reduction in yield or quality.

Background and expected deliverables

The overall aim of the project was 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 were combined with existing non-chemical methods for other pests and diseases in an overall Integrated Pest and Disease Management (IPDM) system, and this was tested and refined in commerical strawberry production over two seasons. In this report we summarise the results from the second year of IPDM assessments in commercial strawberry and include a financial assessment of the strategies.

Summary of results from year 5 and main conclusions

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 IPDM programme (years 4-5, all partners)

An integrated pest and disease management programme was devised in year 4 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 and biocontrol agents together with more species specific controls was developed. Where treatment was required, priority was given to use of natural products, commodity substances and the use of biocontrols (e.g. for aphids). Conventional fungicides or insecticides were only used 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 were not used on fruit, wherever an alternative treatment or chemical was available.

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

IPDM trials were conducted at five sites: four in Kent (two in 2011 and two in 2012) and one in Surrey (trialled for two seasons). Treatment comparisons over the three commercial tunnel strawberry crops in 2011 and 2012 support the use of IPDM to manage pests and diseases. The IPDM strategies used appeared to be as effective as the host grower's standard practices in controlling the key strawberry pests and diseases whilst maintaining equivalent yield and quality with many fewer detections of pesticide residues in fruit.

Pest control

For aphid control, well timed out-of-season sprays were combined with three releases of Aphidsure fragaria (a six parasitoid wasp mix) at three week intervals from the first signs of plant growth prior to seeing aphids. This approach showed promising results in both years at certain sites and has the added benefit of not requiring aphid identification to be effective. However on one site where there was a large population of melon-cotton aphid (*Aphis gossypii*), introduction of the single species parasitoid *Aphidius colemani* was more successful. Most success was achieved where the parasitoids were introduced preventively one to two weeks after the plants start growing.

For strawberry blossom weevil, a grid of super traps developed in the early stages of this project was set out over the IPDM area (36/ha). The pest was successfully detected in the traps but was present at low levels and so did not reach a threshold for control; this was a good result as it avoided an unnecessary insecticide application, which did occur in the grower control at more than one site.

For capsid and European tarnished plant bug control, a combination of approaches was adopted over the different sites including: monitoring traps with lures, alyssum trap plants and bug vaccing. The traps provide a relatively inexpensive way to monitor for the presence of the pest. It allows growers to target spays accordingly or to avoid their use altogether if the pest is not present. These traps are now commercially available. The alyssum did not perform as hoped, struggling to establish and failed to flower before the strawberries. Bug vaccing requires further development, identifying optimal equipment mounting and timing runs through the crop.

For two-spotted spider mite, western flower thrips, and tarsonemid mite control, release programmes of *Phytoseiulus persimilis* and *Neoseiulus* (*Amblyseius*) *cucumeris* (as slow release sachets) were used. These are already widely adopted in the industry but incorporation with a more complete IPM strategy and limiting insecticide applications further, appeared to enhance the efficacy of the of these strategies. Also trialled on a smaller scale was the use of pheromone delta monitoring traps for three common tortrix species found on strawberry, along with the use of sticky glue around table top legs for earwig control. With all these strategies, careful monitoring, placement and early introductions were crucial to success.

Disease control

In terms of disease control, the IPDM strategy focussed on non-chemical control of powdery mildew and botrytis (grey mould) during flowering and harvest. Outside of this period, protective and curative fungicide applications for crown rot, botrytis, powdery mildew and blackspot were applied to clean up the crop and reduce potential inoculum present and protect new growth from re-infection at a time when these products are unlikely to leave a residue on fruit. For powdery mildew, the computer based disease forecasting tool developed in the earlier stages of the project, which uses hourly in-crop temperature and humidity records and disease monitoring, was used to trigger spray applications of potassium bicarbonate and sulphur. Potassium bicarbonate has eradicant properties but provides little protectant activity. Sulphur is mainly a protectant with some eradicant properties. This strategy has shown encouraging results in early season crops with a low mildew pressure, maintaining equivalent levels of mildew control with many fewer fungicide applications required.

For control of botrytis, the bee-dispersed biological control agent (BCA) Prestop Mix (*Gliocladium catenulatum* - used under Extrapolated Experimental Approval), was combined with the use of the BOTEM prediction model and spray application of both Serenade ASO (*Bacillus subtilis*) and Prestop (*G. catenulatum*). These were trialled over the two years. Bumble bees were demonstrated to be more suitable to UK strawberry production systems in polytunnels than honey bees for this mechanism. The native *Bombus terrestris, Audax* species, has been used to transfer Prestop Mix powder to strawberry flowers. In the three crops where this was trialled, equivalent and in some cases lower levels of botrytis was found on the fruit compared with a conventional fungicide programme, although it was not always possible to relate the botrytis control to the amount of Prestop Mix delivered. The BOTEM model was used to trigger spray applications of the two BCAs outside of the bee dispersal periods and on two sites where bees were not used.

Yield and residues

Over the two years and six crops in which the IPDM strategy was implemented only one site was adversely affected in terms of yield and fruit quality and this was as a direct result of an exceptionally high powdery mildew pressure and poor spray coverage. At all other sites the IPDM programme achieved equivalent yield and fruit quality compared to a conventional programme with between 50% and 100% fewer chemical residues detected in fruit.

Financial benefits

Estimated changes in costs due to typical implementation of the IPDM programme are summarised in Table 1 compared with a typical grower programme. The annual total for the IPDM programme varies from an estimated £250 cheaper to £2,800 per hectare more expensive depending on the extent to which the IPDM approaches are adopted and also the crop type and situation. A detailed break-down is available in the science section of the report. The additional cost of the IPDM programme would be £137 per tonne assuming a typical yield of 20 tonne/ha for full adoption of the IPDM programme.

Table 1. Changes in variable costs per ha per annum that are likely to occur typically as a result of implementing the IPDM program in comparison with a typical growers programme

Target pest/disease	Approach	Additional cost/ha/annum £ (excl VAT)
Botrytis	Bee vectored Prestop Mix	+ £ 115
	BOTEM model and timed fungicide applications	Variable depending on weather conditions
Powdery mildew	Applications of fungicide, potassium bicarbonate and sulphur according to forecasting model and field observations	+/- Variable depending on disease pressure and weather 2012 estimate - £300 to - £404
Aphids	Aphid parasitoid 6 wasp mix – 1 tube/200m^2 x 3 introduction at 3 week intervals	+ £ 1,731
Strawberry blossom weevil	Grid of 36 bucket traps and lures per hectare. 10 man hours to service traps	+ £ 449
Two spotted spider mite	High introduction rates of *Phytoseiulus persimilis* at first sight of pest 100k/ha followed by 25k/ha 2 weeks later as required	+ £ 404
Capsids	2 green cross vane bucket traps for European tarnished plant bug, and 2 blue sticky traps for Common green capsid per	+ £ 86

Target pest/disease	Approach	Additional cost/ha/annum £ (excl VAT)
	hectare with pheromones	
Western flower thrips and tarsonemid mites	*N. cucumeris* ABS release sachets, followed by loose product 50/m^2 as required	+ £ 325
Earwigs	Insect barrier glue on table top legs	+ £ 94
Net cost increase		**+ £ 2,800**

Action points for growers

- Results in 2012 at one site in particular highlighted the importance of effective spray coverage. This IPDM programme focuses on reducing and targeting fungicide applications for powdery mildew control and for this to be effective the coverage needs to be complete, especially to the underside of the leaves and to the young leaves and flowers. Understanding sprayer technology, particularly on table top systems, and developing quick easy methods to assess sprayer efficacy to ensure good coverage in the field has been highlighted as requiring further investigation to provide advice to growers. Poor coverage leads to increased numbers of applications and knock-on effects on resistance development in the pest or pathogen and residues in the fruit.
- Several newer strawberry varieties appear to be more susceptible to mildew infection of fruits and flowers. The current powdery mildew model was developed for the conditions conducive to leaf infection. The temperature and humidity parameters for the infection of fruits and flowers appear to be different to those for leaves so the model should not be relied on to predict mildew infection of flowers and fruits.
- For optimum efficacy the aphid parasitoid mixes for aphid control should be released as early as possible, before aphids are seen in the crop.
- Early releases of *Neoseiulus cucumeris* sachets are essential for effective control of thrips and tarsonemid mites.

SCIENCE SECTION

Aim and objectives

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. To this end, the following objectives are being pursued:

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

Progress with objectives and specific tasks

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)
Task 1.2 Effect of nitrogen on the susceptibility to powdery mildew (Y3-4, EMR)
Task 1.3 Determining the control efficacy of BCAs and alternative products (EMR, Y1-4)
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)*
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)
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 plants

Method

Two mycelial plugs of isolates of *Colletotrichum* spp. from various hosts (Table 3.2.1) were placed onto Potato Dextrose medium (PDA) and the plates incubated at 25^oC 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.

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 by misting for 30 mins three times each day. Four replicates were prepared per isolate and each replicate consisted of 8 plants.

After inoculation the plants were inspected weekly for signs of infection. After three months (6 July 2012) the plants were scored for blackspot lesions using scoring system (Table 3.2.1).

Results and discussion

Black lesions or reddish spots developed on the petioles of most plants inoculated. Very few lesions were observed on the uninoculated controls (Table 3.2.2). Sporulating colonies of *C acutatum* were detected. The highest pathogenicity scores in the plant tests were on plants inoculated with isolates from apple, willow herb as well as strawberry.

The results of the pathogenicity tests on fruit and plants are summarised in Table 3.2.2. There was variation in pathogenicity between isolates from different hosts on strawberry fruit and plants over the tests but this was not always consistent. However all isolates from the different hosts were able to infect strawberry fruit or plants. The results from the fruit and plant inoculations indicate that weeds and other non-strawberry hosts could act as a source of inoculum for *C. acutatum* in strawberry plantations.

Table 3.2.1 Pathogenicity of isolates of *Colletotrichum* sp. from various hosts on strawberry plants inoculated on 24 April 2012 and assessed on 6 July 2012

Isolate number	Host origin	Mean pathogenicity score on strawberry plants cv. Elsanta
1	Strawberry, Isle of Wight	2.2
3	Weed, EMR	2.0
4	Willowherb, EMR	2.6
9	Alde,r EMR	1.8
10	Apple cv. Bramley, Chartham	0.8

11	Apple cv. Bramley, Kent	0.7
12	Apple cv Bramley, Ightham	1.4
13	Primula	1.6
14	Strawberry, SC196 EMR	2.4
16	Strawberry, SC201 EMR	1.7
17	Apple cv. Bramley, Hospital Farm	1.5
19	Apple cv. Gala, Rocks Farm EMR	2.5
21	Blueberry, A G Thames	1.3
22	Cherry, Sidnalls Farm, Ullingswick, Herefordshire	2.0
	Uninoculated	0.5

Plant score

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

Table 3.2.2 Pathogenicity of isolates of *Colletotrichum* sp. from various hosts on strawberry fruit and plants inoculated at various times in 2010, 2011 and 2012

Isolate number	**Host origin**	**Mean pathogenicity score on fruit cv. Red Glory inoculated 30/11/2010**	**Mean % fruit cv. Premier infected with blackspot inoculated 16/11/2011**	**Mean pathogenicity score on strawberry plants cv. Elsanta inoculated 20/12/2010**	**Mean pathogenicity score on strawberry plants cv. Elsanta inoculated 24/04/2012**
1	Strawberry, Isle of Wight	2.2	28.1	1.8	2.2
2	Strawberry, Suffolk	2.3	-	2.0	-
3	Weed, EMR	1.4	21.9	1.3	2.0
4	Willowherb, EMR	1.8	18.8	2.0	2.6
5	Willowherb, EMR	1.8	-	1.5	-
6	Willowherb, EMR	1.9	-	1.5	-
7	Alder, EMR	3.0	-	2.3	-
8	Alder, EMR	2.2	-	1.8	-
9	Alder, EMR	2.3	18.8	2.0	1.8
10	Apple cv. Bramley, Chartham	3.1	12.5	1.8	0.8
11	Apple cv. Bramley, Kent	2.5	-	1.3	0.7
12	Apple cv Bramley, Ightham	2.7	34.4	2.3	1.4
13	Primula	2.0	12.5	2.0	1.6
14	Strawberry, SC196 EMR	-	25.0	1.3	2.4
16	Strawberry, SC201 EMR	-	18.8	-	1.7
17	Apple cv. Bramley, Hospital Farm	-	18.8	-	1.5
19	Apple cv. Gala, Rocks Farm EMR	-	18.8	-	2.5
20	Apple cv. Gala, Clockhouse Farm	-	12.5	-	-
21	Blueberry, A G Thames	-	12.5	-	1.3
22	Cherry, Sidnalls Farm, Ullingswick, Herefordshire	-	15.6	-	2.0
	Uninoculated			1.3	0.5

Fruit score 0 = No infection, 1 = Small lesion, 2 = Large lesion no sporulation, 3 = Large lesion sporulation, 4 = Large lesion sporulation + mycelium growth, 5 = Completely rotted fruit

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

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

In the Hortlink biofumigation project SF 77 / HL0177 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 (jar tests).

Methods

Strawberry petioles were inoculated with a spore suspension of four isolates of *C. acutatum* prepared as in Task 3.2. The petioles were incubated in high humidity under UV light at ambient temperature to allow blackspot development and sporulation. The infected petioles with sporulating colonies of *C acutatum* were then chopped up and used as the debris for the jar tests.

Products evaluated were Biofence pellets (produced from mustard crop), pelleted lavender waste and micro-encapsulated lavender terpenoids (Table 3.3.1). Test products were compared to an untreated control. The test products were placed in the bottom of honey jars to which soil and strawberry debris infested with *C. acutatum* was added. The jars were sealed and incubated at 25^{o}C for one month after which the strawberry debris was recovered and plated onto two different selective media (MS media and DPYA) to test the survival of the *C. acutatum*. The tests were repeated twice.

Table 3.3.1. Treatments evaluated in biofumigation tests in jars in 2012 and 2013

Treatment	Product	Rate/kg soil	Rate/200 g soil
T1	Untreated	-	-
T2	Biofence	1.6 g/kg soil	0.32 g
T3	Lavender pellets	6.5 g	1.3 g
T4	Lavender pellets	13 g	2.6 g
T5	Terpenoids	150 micro L	30 micro L
T6	Terpenoids	50 micro L	10 micro L

Results and discussion

In both tests the incidence of *C acutatum* that developed on the selective media plates from the untreated controls was very low. *C. acutatum* was also detected, at a very low incidence, on the selective plates from all the fumigation treatments, suggesting that none of the fumigants had been successful in eliminating the *C. acutatum* from the debris. However, further tests will be conducted in field biofumigation experiments as part of another project before any final conclusions are drawn on product efficacy.

Task 3.4: Development of simple guidelines for blackspot management

Simple guidelines were developed to assist growers in making decisions regarding the need for management measures against blackspot, based on published data and newly available information on blackspot from this project. These guidelines include a risk assessment of factors likely to influence the incidence of blackspot in a strawberry crop including – site, source of planting material, cropping system, crop age, cultivar, irrigation, nutrition, adjacent crops and herbicide use. Other factors included are weather (temperature, humidity and rainfall), fungicide efficacy and importance of non-chemical control methods. This information will be used to update the HDC Factsheet on blackspot.

Objective 4. To develop an IPM system for European tarnished plant bug on strawberry using a trap crop, a semiochemical female repellent 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)

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

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)

Task 5.2. Evaluate the effectiveness of plant derived semiochemicals to attract aphid predators and parasitoids (EMR/NRI, Yrs 1, 2, 3) Plus an additional experiment was done in year 4.

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)*

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)

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

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

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

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

Work completed.

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)

This is reported in Task 7.2.

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 and biocontrol agents together with more species specific control was developed. These systems were evaluated in large commercial plots. Where treatment was required, priority was given to use of natural products and commodity substances, the use of biocontrols (e.g. for aphids) and 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 used on fruit wherever an alternative treatment or chemical was available.

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

2011 results are detailed in the 2011 annual report. 2012 data only are detailed in this report but conclusions and findings resulting from both years of trial are discussed.

The IPDM strategy devised in 7.1 was tested in comparison with the standard commercial programme used at the time by the host grower at three sites in England: one in Surrey at Tuesley Farm and two in Kent at Manor Farm, Ightham and Middle Pett Farm, Bridge. The IPDM strategy and a Grower standard programme (GS) – the standard commercial programme - were applied to large plots of protected strawberries. The Tuesley Farm site was planted with cv. Elsanta in March 2011, the Manor Farm site was planted with cv. Amesti w/c 19 March 2012 and the Middle Pett Farm site was planted with cv. Elsanta on 20 June 2012.

Site 1: Tuesley Farm, Godalming Surrey – Trial plan

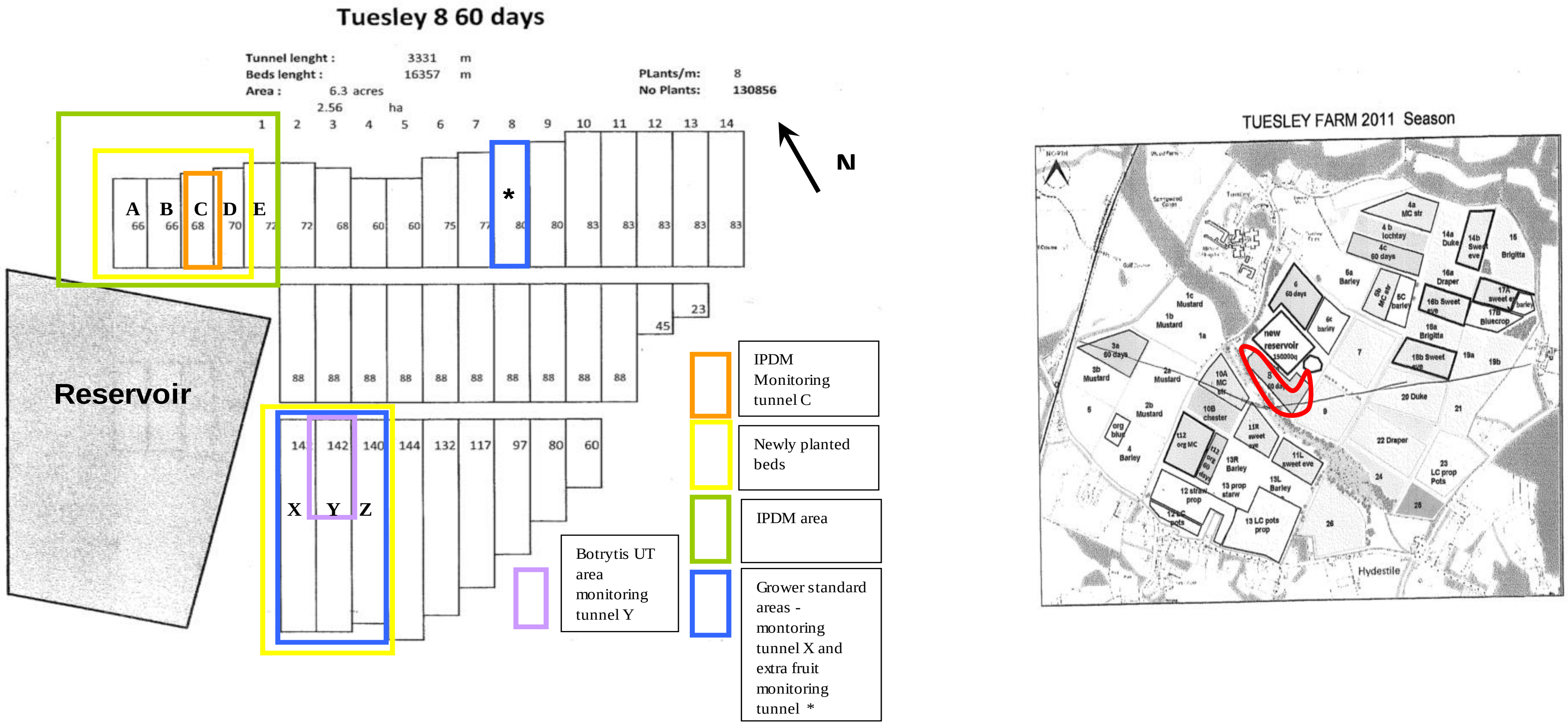

Figure 7.2.1. Trial Plan IPDM trial - Tuesley Farm Godalming, Surrey 2012 (Tunnel Y managed as the GS but without any fungicides for Botrytis. An extra grower standard tunnel was included at second fruit sampling to get an extra comparison with the IPDM as due to the topography of the field tunnels X, Y, Z were slightly warmer and wetter than at the IPDM end of the field). Please note there was replication of fruit samples taken and assessed within each treatment, but there is no on-site replication of treatments. The same/similar treatments are being tested on two other sites in Kent by EMR. Results should be treated with caution until the full data set and statistical analysis is available.

Table 7.2.1. Tuesley site - summary of monitoring activities and IPM measures implemented - 2012

A: Description of each site						
Farm	Location	Planting date	Date covered in 2012	Variety	Surrounding plants	Other observations
Tuesley Farm	Godalming Surrey	28 March 2011	6 February 2012 Fleeced 8 February 2012	Elsanta	Blueberries and everbearer strawberries	IPDM tunnels to SE of GS tunnels. GS down slope with reservoir to the N.

B: summary of monitoring activities and IPM measures implemented									
Growth stage	Monitoring/assessments		Disease			Pests			Other notes
	Date	Advice (protocols)	IPM measures adopted		Growers	IPM measures adopted		Growers	
			Date	Measures		Date	Measures		
Post-harvest 2011	15 Jul	Full P&D assessment Residue samples taken	13 Jul	Potassium bicarbonate and sulphur applied for mildew	Potassium bicarbonate for mildew				Every second plant removed and crop topped
			27 Jul	Fortress applied for mildew	Fortress applied for mildew				
			6 Aug	Alliette for crown rot, Systhane for mildew	Alliette for crown rot, Systhane for mildew	6 Aug	Abamectin and Apollo for tarsonemid and spider mite	Apollo and Dynamec for Spider mite and tarsonemid	Dow Shield applied for weed control
	17 Aug	Full P&D assessment	12 Aug	Corbel for mildew	13 and 20 Aug Corbel for mildew				
			27 Aug		Systhane 20 EW for mildew	27 Aug		Sequel for tarsonemid	
			3 Sep – 4 Oct		Stroby WG, Corbel, Topas, Stroby WG, Systhane 20EW, Topas all for Mildew	12 Oct	Calypso for aphids	Calypso for aphids	
	12 Oct	Autumn P&D	12 Oct	Systhane 20EW	Systhane 20EW for				

		assessment		for mildew	mildew				
Pre flowering 2012	2 Feb	Pest and disease assessment	2 Feb	Loggers set up in crop to be downloaded weekly. Additional Botrytis UT tunnel marked out		7 Feb	Strawberry blossom weevil traps set up, Aphidsure fragaria and *Amblyseisus cucumeris* sachets put out under fleece	Equity applied for Aphid and caterpillar	Crop cleaned trash removed. Crop to be fleeced till flowering.
			17 Feb	Rovral WG, Thianosan DG2 for Botrytis	Rovral WG, Thianosan DG2 for Botrytis				Devrinol ad Reglone for weed control
Flowering 2012	22 Mar	Pest and disease assessment		Bumble bees introduced without Prestop Mix. Mildew Model alert spray- Fortress	Fortress and Switch for Botrytis and powdery mildew	24 Mar	*A. cucumeris* and Aphidsure released.		Fleece removed
	27 Mar	full assessment		No mildew observed at assessment		27 Mar	Large number of aphids in IPDM plots no other pest Advised a Chess application to knock back aphids. Aphidsure tubes delayed delivery by 1 week. Lygus traps put out	Calypso for aphids	

Flowering 2012	10 Apr	Full assessment	10 Apr	Prestop Mix refreshed twice a week. Flowers sampled, Some leaf curl observed on the gapped up plants possible mildew so Pot bicarb spray requested (11 Apr)	3 Apr - Stroby WG, Teldor, 10 Apr - Systhane 20EW, Scala 17 Apr – Topas and Switch applied for powdery mildew and Botrytis	10 Apr	Aphid numbers lower but still present, no mummies observed. second Aphidsure and first *Phytoseilus persimilis* release	Aphox applied	3 Apr - Aliette 80 WG applied 17 Apr Sluxx and Harvest applied
	24 Apr	Full assessment	24 Apr	Flowers sampled. Pot bicarb spray requested (applied 26 Apr)	26 Apr – Amistar and Teldor 1 May – Systhane 20 EW and Signum	24 Apr	High numbers of aphids and honeydew, 1x *L. rugulipennis* and 2x thrips were found in the IPDM tunnel. Calypso application requested (26 Apr) *Amblyseius cucumeris* released		
Harvest 2012	9 May	Full assessment plus fruit assessment	9 May	Fruit samples collected and put into either storage regime - waste was mainly due to botrytis and	Rovral applied 14 May – Scala applied 17 May – Nimrod and Teldor applied	9 May	Aphid levels had reduced but there were still lots remaining and only three		

				some cat facing	21 May – Teldor applied		mummies, Majestik (applied 17 May) Some TSSM and thrips observed.		
Harvest 2012	23 May	Full assessment plus fruit assessment		Fruit collected from the three monitoring tunnels plus an extra GS. Flower samples sent to Verdera to try and detect the Gliocladium. In the GS tunnel a UV powder was introduced to the unused dispenser to use as a model tracer			*Phytoseilus persimilis* released		
	28 May			Pot bicarb requested based on alert, leaves appeared to be cupping slightly no mycelium observed			Aphid numbers still high and building lots of nymphs and no mummies. Spruzit requested for aphid control		
	29 May					30 May	Spruzit applied May		

							Aphidsure applied		
Harvest 2012	7 June	Full assessment		Prestop Mix replenishment stopped, Fruit samples collected			Aphid population reduced with some plants having more mummies than aphids		
	15 June	Consortium visit - Trial open day							
	26 June	Full assessment							Trial packed up

Site 2: Manor Farm, Ightham, Kent

Cultivar: Amesti

Planted: w/c 19 March 2012.

Experimental set up: using ‘Block 3’; tunnels 6.8 m wide, bed spacing 1.5 m with four beds per tunnel, plants spaced 40 cm apart in raised beds on poly mulch. Three tunnels used for IPDM and for the Growers Standard (control) programme. This site was monitored by EMR.

Husbandry: plants were de-blossomed in early May. On 16 May the Grower Standard (GS) area had been de-blossomed while the IPDM area had not yet been de-blossomed. No early weed control was possible as the site was too windy for herbicide application. Tunnels were covered 16 May. Weeds were strimmed w/c 28 May.

Biocontrol releases:

6 April: Aphidsure fragaria (parasitoids mix for aphid control) was put out in IPDM area. Ambsure abs sachets that were ordered for this week were cancelled as the plants were too small to support the sachets.

19 April: After discussion with the host grower about the growth of the plants, the second order for Aphidsure fragaria was cancelled as the weather forecast was poor with heavy rain and hail, the tunnels had not gone up and the plants had not developed.

18 May: Aphidsure fragaria put out in IPDM area.

23 May: Ambsure abs sachets (for tarsonemid/thrips control) put out.

21 June: Aphidsure fragaria put out.

28 June: Ambsure abs sachets put out. *Orius laevigatus* released (for thrips control).

12 July: Aphidsure fragaria put out and *Orius laevigatus* released.

19 July: Phytosure (p) released (for spider mite control).

27 July: Aphisure (*A. colemani*) released (for aphid control).

30 Aug: Loose *A. cucumeris* released (for thrips control).

Trap plants

6 June: Grow bags had been set up in the leg rows of the IPDM plot and fully watered (set up on separate irrigation line to strawberries). Alyssum (cv. Clear Crystal) was transplanted into bags from plug plants grown at EMR. Seventy bags were planted up by EMR staff. The bags were raised off the ground to improve drainage.

27 June: The Alyssum plants were not growing well and were being drenched with rainfall from the polytunnel eaves. The bags were moved closer to the strawberry plants and partly under the poly covers. Fertiliser was applied in the irrigation water.

Bugvac

Early July: Collected from previous host grower.
12 July: First use but with Bugvac mounted on back of tractor it did not fit inside the tunnels and needed modification.

25 July: The Bugvac was successfully modified and used. The Bugvac treatment as subsequently done on 7 and 15 Aug and 5, 13 and 23 Sept.

Pesticide applications

A summary of pesticides applied is given in Appendix 1.

Site 3: Middle Pett Farm, Bridge, Kent

Cultivar: Elsanta on table tops

Planted: 16 July 2012

Experimental set up: using ‘Store Field block 6’; four table tops in each 8 m tunnel with eight plants to each coir bag. Tunnels were 90 m long. Three tunnels were used for the IPDM and for the Grower Standard programme. This site was monitored by EMR.

All pest monitoring traps were put out on 3 August. For capsids two traps for each species were placed in each plot between the coir bags. For SBW two traps were placed in the Grower plot. A grid of 10 traps was placed in the IPDM tunnels. One trap for each moth species was placed in each plot. Lures were changed in all except SBW traps every four weeks.

Biocontrol releases:

w/c 6 Aug: Aphidsure fragaria put out. Ambsure abs sachets put out .

Pesticide applications

A summary of pesticides applied is given in Appendix 1.

7.2.2. Pest monitoring

Materials and methods

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 vanes (Agralan Ltd., UK). The traps were filled with water and the number of males caught was counted at least every two weeks and the water was refreshed. The *Lygocoris pabulinus* traps were blue sticky traps with the lure attached to the sticky trap. The traps were checked for adult capsids at least every two weeks.

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 four-six weeks.

Strawberry blossom weevils were monitored in the Grower Standard area using two pheromone traps. These were green bucket traps with white cross vanes and a plastic grid guard below the cross vanes 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 two 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 Kent 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 Middle Pett and 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 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 two weeks after planting or growth starting with one tube per 200 square metres, with three 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 Certis, UK) were introduced at one sachet per 2 m length of bed before flowering when temperatures were above 12 °C. This was repeated every six-eight weeks where necessary. For control of two-spotted spider mite, *Phytoseiulus persimilis* (Phytosure from BCP Certise, UK) were introduced at 10 per square metre at the first sign of any spider mites. This was repeated every two weeks where necessary.

At Manor Farm for Capsid control, Alyssum (Clear Crystal) trap plants were planted into grow bags set up in the leg rows of the IPDM plot and fully watered (set up on separate irrigation line to the strawberries). Initially the plants did not establish well as they were being flooded with rainfall from the poly tunnel eaves. The bags were moved closer to the strawberry plants and partly under the poly covers and growth improved. These plants were monitored for the presence of *Lygus rugulipennis* and spot sprayed with a pyrethrum if the pest was observed. Also trialled at this site was the use of a 'Bugvac' initially back mounted on the tractor but with some modification was switched to front mounted and vaccing was carried out weekly in the late summer

Results

Tuesley site IPM results

Aphids

The first Aphidsure fragaria releases went on under a crop fleece in February it was hoped the wasps would be able to forage under the fleece and parasitise any overwintered aphids. The unusually cold spring and long period of time the crop was fleeced for meant that when the fleece came off and the next lot of Aphidsure was applied aphid numbers had built rapidly in the intervals between re-application of the parasitoid. This high starting level of *Macrosiphon euphorbiae* contributed to the low levels of aphid parasitism seen in the early part of the year and allowed aphid numbers to increase unchecked. Because of this an insecticide had to be used to bring the numbers under control and avoid crop damage. Mummies were seen from late May following a fourth application of the parasitoids when aphid numbers had declined a little following the application of Calypso (thiacloprid) and when conditions were warmer.

Table 7.2.2. Aphid and mummy counts in IPDM and Grower Standard tunnels, Tuesley 2012

		Average no. /plant		**Total no. found on 50 plants**	
2012		**IPDM**	**GS**	**IPDM**	**GS**
02-Feb	Aphids	0.00	0.00	1	0
	Mummies	0.00	0.00	0	0
27-Mar	Aphids	19.72	0.00	986	0
	Mummies	0.02	0.00	1	0
10-Apr	Aphids	11.48	0.04	574	2
	Mummies	0.10	0.00	5	0
24-Apr	Aphids	46.44	0.00	2,322	0
	Mummies	0.04	0.00	2	0
09-May	Aphids	40.76	0.00	2,038	0
	Mummies	0.06	0.00	3	0
24-May	Aphids	19.02	0.00	951	0
	Mummies	0.06	0.00	3	0
07-Jun	Aphids	5.74	0.44	287	22
	Mummies	2.24	0.00	112	0
26-Jun	Aphids	0.04	0.08	1	4
	Mummies	0.80	0.02	20	1

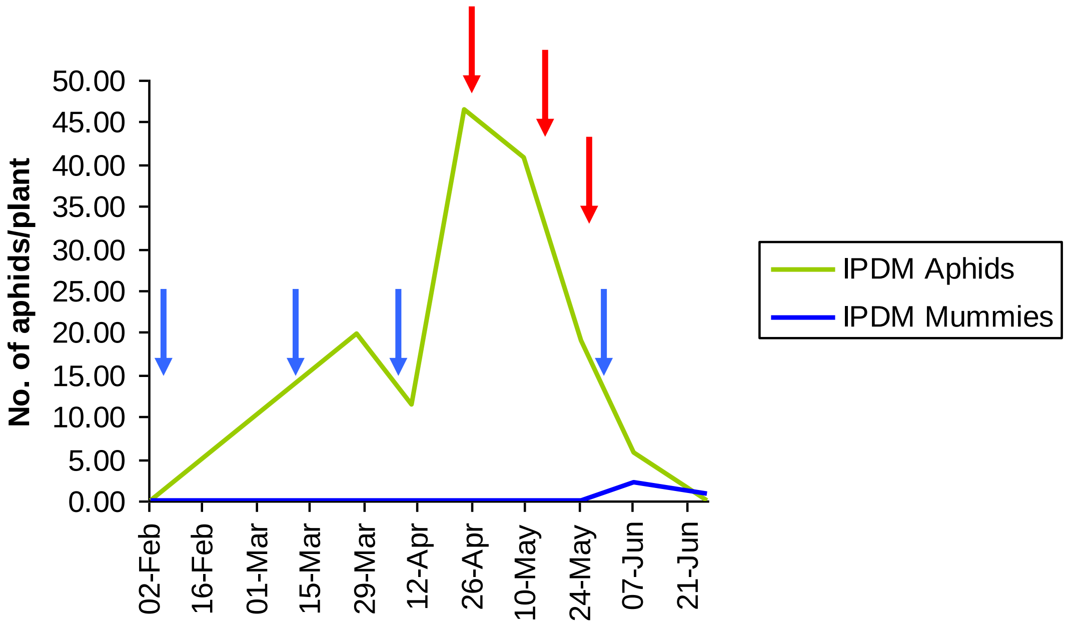

Figure 7.2.2. Counts of aphids and parasitoid mummies. Tuesley Farm 2012. Blue arrows show Aphidsure fragaria release dates 7/2, 24/3, 12/4 and unprompted grower release 30/5. Red arrows show Insecticide applications 1 – Calypso, 2 – Majestik and 3. Spruzit

Mites

Tarsonemid mites were observed from early May. Numbers built to very high levels in the Grower Standard with over 20 found in an individual leaf tip. Levels were always lower in the IPDM plot, with *N. cucumeris* observed alongside the tarsonemid mites.

Two spotted spider mites were observed at low levels from mid April. These numbers built till the end of the trial. Levels of spider mite were again lower in the IPDM tunnel compared to the GS and in general more predatory mites were observed alongside the spider mites in the IPDM plot; these were a mix of *Phytoseilus persimilis* and an unidentified mite.

The GS received no acaricides through the growing season. The host farm used biocontrols for the control of mites to a large extent and the GS received *Phytoseilus persimilis* at a rate of 25k per ha compared to the IPDM rate of 100k per ha. No *N. cucumeris* were applied in the GS area this year.

Table 2.2.3. Comparison of two spotted spider mites and tarsonemid mites over the growing season, total mites found on 50 leaf tips (tarsonemid) and 50 trifoliate leaves (two spotted spider mites) – Tuesley Farm 2012

	Tarsonemid				Two spotted spider mites			
	No. of adult mites		Predatory mites		No. of adult mites		Predatory mites	
Date	IPDM	GS	IPDM	GS	IPDM	GS	IPDM	GS
07-Feb	0	0	0	0	0	0	0	0
27-Mar	0	0	0	0	0	0	0	0
10-Apr	0	0	0	0	9	1	1	0
24-Apr	0	0	0	0	0	0	0	0
09-May	7	3	1	0	1	63	1	0
07-Jun	3	535	0	0	53	1,159	1	1
26-Jun	0	1,063	2	0	271	1,968	5	2
Total	10	1,601	3	0	334	3,191	8	3

Strawberry blossom weevil, capsid bugs, thrips and caterpillars

Overall the level of other pests was relatively low throughout the growing season in 2012. No strawberry blossom weevils were found in the crop and there were low numbers of severed flower heads in the GS tunnel in mid April. The blossom weevil traps were emptied by farm staff. Similar numbers of blossom weevils were caught, with slightly more in the IPDM than in the GS.

Low numbers of thrips were observed. A sample of these were collected and confirmed as western flower thrips. Fewer were found in the IPDM plot but observations were very variable.

Only one *Lygus rugulipennis* was captured throughout April and May in 2012.

Table 7.2.4. Total number of pests found on 50 plants assessed throughout the growing season – Tuesley Farm 2012

Date	Strawberry blossom weevil tap sample on 50 plants/tunnel		Number of severed flower buds per plant 50 plants /tunnel		Thrips - 50 flower tap samples	
	IPDM	GS	IPDM	GS	IPDM	GS
07-Feb	0	0	0	0	0	0
23-Mar	0	0	0	1	0	0
10-Apr	0	0	0	8	0	0
24-Apr	0	0	0	0	2	0
09-May	0	0	0	1	0	0
23-May	0	0	0	0	1	10
07-Jun	0	0	0	2	0	0
Total	0	0	0	12	3	10

Table 7.2.5. Strawberry blossom weevil and capsid bug trap counts counted by farm staff – Tuesley Farm 2012

Date	Strawberry blossom weevil		*Lygus ruglipennis*		*Lygus pabulinus*	
	IPDM	GS	IPDM	GS	IPDM	GS
20-Feb	0	0				
01-Mar	0	0				
18-Mar	0	0				
01-Apr	0	0	0	0	0	0
16-Apr	4	3	1	0	0	0
01-May	2	3	0	0	0	0
14-May	6	1	0	0	0	0
29-May	1	3	0	0	0	0
04-Jun	2	0				
Total	15	10	1	0	0	0

Manor Farm IPM results

Capsids

The Alyssum plants took some time to begin flowering in the coir bags (Figure 7.2.3). After providing cover from the rain and a fertiliser treatment they began to grow more robustly, but suffered from rabbit feeding. Netting was erected by the grower to reduce the damage. By the end of July they were flowering well; this continued throughout August. However, at the time of peak adult capsid numbers (during July) the strawberries were flowering profusely, so the adults moved directly onto the strawberry plants and the trap crop was relatively ineffective. On 10 July there were three capsid adults and two nymphs in the tap sample of strawberry and three adults but no nymphs on an equivalent sample of Alyssum. On 31 July there were 23 capsid nymphs on the strawberry and no capsids on the Alyssum.

26 June 2012

10 July 2012

31 July 2012

5 September 2012

Figure 7.2.3. Growth of Alyssum plants at Manor Farm

Numbers of capsid males caught in pheromone traps in the Grower Standard area were higher than in the IPDM plots at the beginning of the season (Figure 7.2.4.). This may have been because the Grower Standard tunnels were adjacent to a large weedy field whereas the IPDM tunnels were adjacent to grassland. The grower applied chlorpyrifos to the Grower Standard plot on 5 June and subsequently no capsid nymphs were recorded in taps of plants in these tunnels (Figure 7.2.5). In the IPDM plot bug vaccing began on 25 July, rather later than planned due to modifications being required before it could be used effectively. By this time capsid numbers had begun to increase on this plot (Figure 7.2.5); on 31 July there were 23 nymphs on 75 plants (i.e 0.3 per plant) and by 17 August there were 35 nymphs and 12 adults per 75 plants (i.e. 0.5 nymphs and 0.2 adults per plant). Because of this the grower was asked to apply Chess (pymetrozine) on 28 August; this reduced the population to low levels (Figure 7.2.5). The bug vaccing was then continued to keep these populations low.

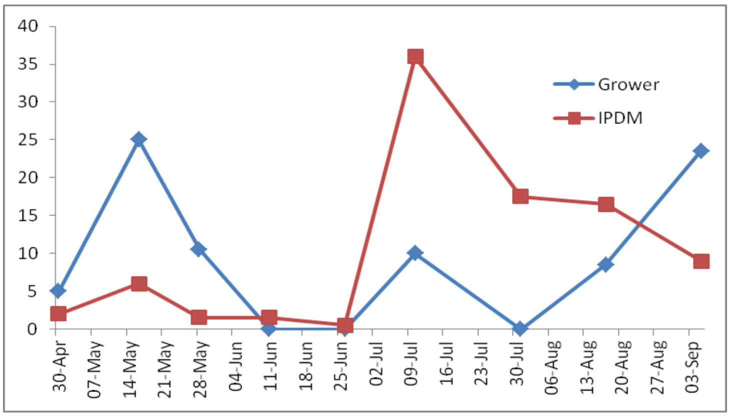

Figure 7.2.4. Mean number of *Lygus rugulipennis* males recorded in pheromone traps in the IPDM and Grower Standard plots

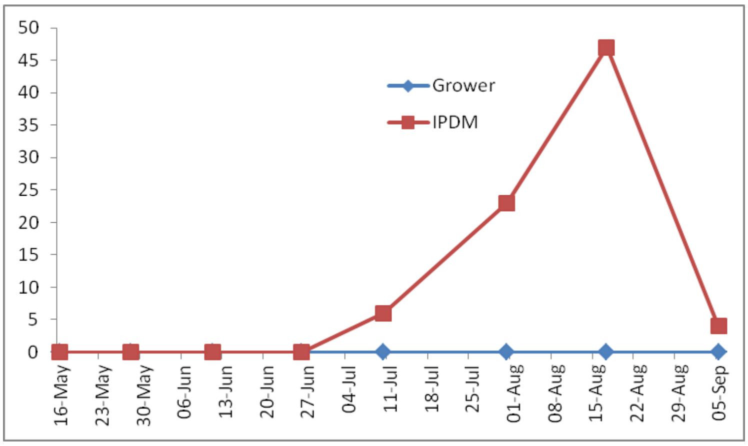

Figure 7.2.5. Total numbers (all stages) of *L. rugulipennis* recorded in taps of 75 plants in the IPDM and Grower Standard plots

Samples of waste fruit collected on two occassions showed higher capsid damage in the IPDM plot compared to the Grower Standard. On 12 September 24.8% of waste fruit in the IPDM tunnels was mis-shapen (possibly caused by capsid feeding) compared to 13.9% in the Grower Standard, and on 28 September these values were 13% and 3.3% respectively. Thus in this year, on this site, the combination of trap crop and bug vaccing was not sufficient to maintain low capsid populations in the crop and to reduce subsequent fruit damage.

Strawberry blossom weevil

A mean of two SBW adults was recorded in the Grower Standard plot on 28 May (Figure 7.2.6). The grower's advisor had also recorded some severing of flowers in this plot and a chlorpyrifos was applied on 5 June. Numbers of SBW caught subsequently were low until later in the season. In the IPDM plot numbers peaked at a mean of one per trap in early July. Very few SBW adults were recorded in tap samples of the strawberry plants and little flower severing was seen in either plot throughout the remainder of the season.

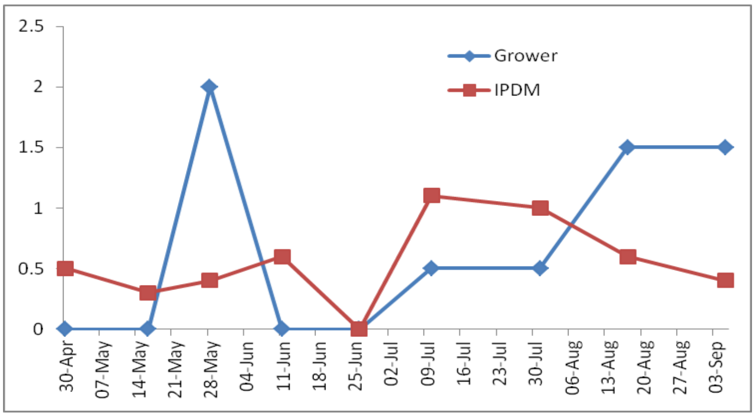

Figure 7.2.6. Mean numbers of strawberry blossom weevil adults per trap in the IPDM and Grower Standard plots

Thrips

After an initial peak of thrips numbers in both Grower Standard and IPDM plots numbers remained at less than one per flower until 11 July in the IPDM plot and until early August in the Grower Standard plot (7.2.7). In the Grower Standard plot Tracer was applied on 17 and 26 August to reduce thrips numbers. However, there is little evidence from the samples taken post application that the pesticide was effective (7.2.7); on 5 September numbers remained at *c*. 1 per leaf. *N. cucumeris* had been released in the IPDM plot. Numbers had increased to 0.4 per flower in early July (7.2.7). However, these releases did not maintain thrips populations at low levels; thrips numbers increased until 15 August when they peaked at 2.8 per flower.

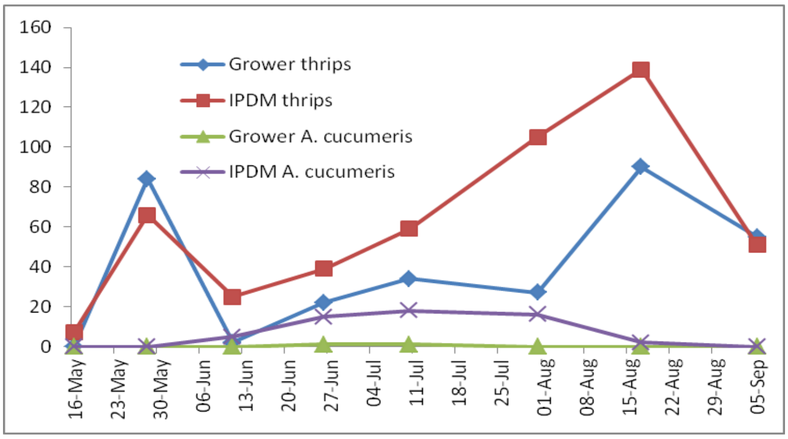

Figure 7.2.7. Total number of thrips (larvae plus adults) and predatory *N. cucumeris* in samples of 50 open flowers in the IPDM and Grower Standard plots

Aphids

In the Grower Standard plot the initial high numbers of aphids on the young leaves was reduced by the application of chlorpyrifos on 5 June (Figure 7.2.8); numbers on the old leaves were also reduced.

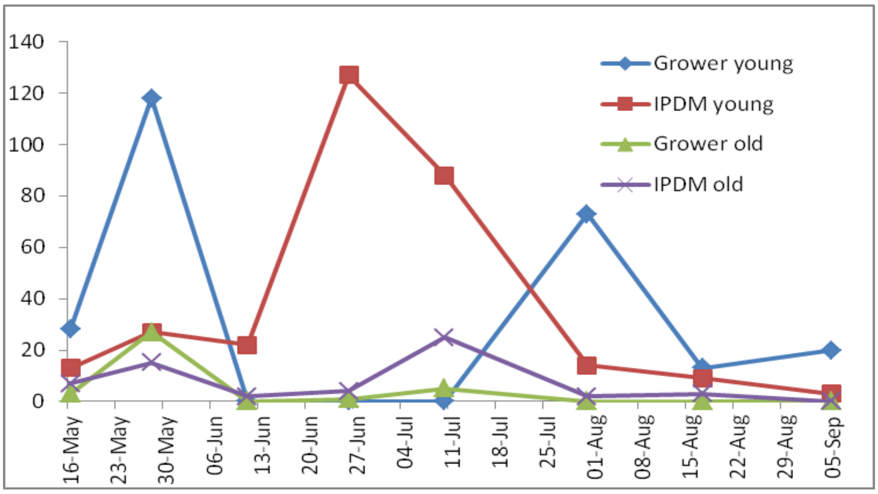

Figure 7.2.8. Total number of aphids on 25 old or young (folded) leaves in the IPDM and Grower Standard plots

Most of the aphids on the young leaves were *Macrosiphum euphorbiae* (potato aphid); this species was still the most abundant species on the older leaves but *Chaetosiphon fragaefolii* (strawberry aphid) and *Myzus ascalonicus* (shallot aphid) were also present. In the Grower Standard plot numbers of aphids increased in early August (Figure 7.2.8). An application of Hallmark (lambda cyhalothrin) was made on 9 August to reduce populations. In the IPDM plot there was an increase in aphid numbers in June despite the initial parasitoid introductions on 6 April and 18 May. However, numbers declined during July and August after parasitoid releases on 21 June, 12 and 27 July. The last release was of a single parasitoid species (*A. colemani*) as *Aphis gosypii* (melon cotton aphid) was the only species present.

Mites

No tarsonemid mites were recorded from either plot throughout the season. Spider mite (*Tetranychus urticae*) were higher in the Grower Standard plot than in the IPDM plot where *P. persimilis* was released on 19 July when spider mites were first seen (Figure 7.2.9). In the Grower Standard plot Masai and Borneo (tebufenpyrad and etoxazole) were applied on 31 July and numbers of spider mites decreased. However, numbers increased again during August in the Grower Standard plot and on the last sample date (25 September) there was a mean of over 700 eggs and nearly 300 actives per leaf.

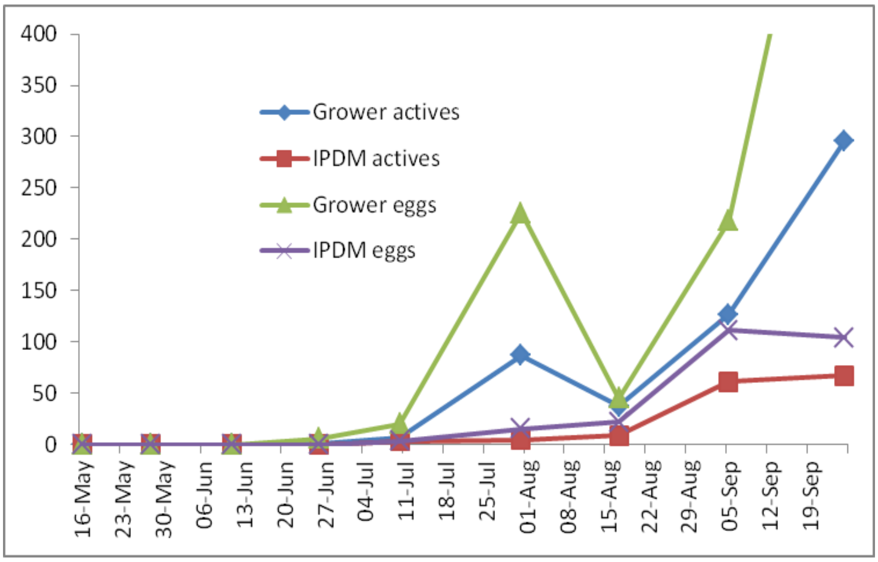

Figure 7.2.9. Mean numbers of *T. urticae* eggs and actives per old leaf in the IPDM and Grower Standard plots. Numbers of eggs in the Grower Standard plot increased to over 700 per leaf by 25 September

Other pests

No *Lygocoris pabulinus* were found in the pheromone traps set out for this species.

Pheromone traps were put out for the moth species *Cnephasia longana*, *Clepsis spectrana* and *Cnephasia interjectana*. Over the entire season a total of only three *C. longana* and eight *C. spectrana* were caught in the traps.

Middle Pett Farm IPM results

Very few arthropod pests were seen throughout the experiment. A mean of 6 and 7.5 *Lygus rugulipennis* were recovered per trap in the Grower Standard and IPDM plots on 20 August; two weeks later there was a mean of 1 and 2 per trap in these plots respectively. One nymph and one adult were recorded in tap samples from the Grower Standard plot and one adult in the IPDM plot on 6 September. Aphids were also recorded in low numbers in both plots;

these were mostly *Macrosiphum euphorbiae*. No spider mites were seen on leaves. No SBW were caught in traps and no severing damage was seen.

7.2.3. Management of powdery mildew

Methods and results

Tuesley Farm

Two temperature and humidity loggers were placed in the IPDM and GS monitoring tunnels for use with the powdery mildew prediction model developed by EMR to detect conditions conducive for this disease as a basis for timing sprays of potassium bicarbonate.

Powdery mildew did not start to develop until the end of June. Scores before this were observations of possible symptoms i.e. leaf cupping and rolling which were probably a result of stress on the plants causing plants to wilt due to the extreme fluxes in day and night temperatures in April and May (Table 7.2.6). This was particularly evident in the gapped up new plants with a less well-established root system.

Table 7.2.6. Percent of leaves showing powdery mildew symptoms – Tuesley Farm 2012

	% leaves showing symptoms	
2012	IPDM	GS
07-Feb	0	0
23-Mar	0	5
10-Apr	(21)*	(10)*
24-Apr	1	0
09-May	4	4
23-May	7	2
07-Jun	0	4
26-Jun	22	7

( )* cupping & rolling which can indicate latent powdery mildew, but was probably water stress

Table 7.2.7 summarises the sprays applied for mildew control in the IPDM tunnels and the stages at which alerts were identified. Alerts were based on in-crop temperature and humidity records (downloaded weekly by the farm staff and emailed to EMR to be used with the computer model) together with observations of actual powdery mildew levels when the logger data was collected from the field. There were three alerts over the season and two applications of potassium bicarbonate and two of conventional fungicides (this should have only been one – Fortress as a protectant once the fleece came off, but an unrequested Amistar (azoxystrobin) application ws made on 26 April). The Grower Standard received seven fungicides for powdery mildew control from March to June and had lower levels of mildew by the end of harvest.

Table 7.2.7. Summary of powdery mildew spray applications in the IPDM tunnels triggered by computer forecasting model alerts based on temperature and humidity data – Tuesley Farm 2012

Alert date	Spray date	Product applied	Active	Spray triggered by model
Post harvest clean up	12/08/11	Corbel post harvest		Requested
Post harvest clean up	12/10/11	Systhane 20EW	Myclobutanil	Requested
13 and 26 March	27/03/12	Fortress	Quinoxyfen	Requested
Possible symptoms spray triggered	11/04/12	Potassium bicarbonate		Requested
	20/04/12	Amistar	Azoxystrobin	Not requested
Possible symptoms spray triggered	26/04/12	Potassium bicarbonate		Requested
22 May alert				Requested not applied

Manor Farm

No mildew was detected at this site. Up to 8 June the same programme was used in the IPDM as in the Grower Standard plots. Thereafter sulphur + potassium bicarbonate (10 sprays) for mildew were applied according to the mildew prediction model. The Grower Standard plot used 23 sprays for mildew (see Appendix 1)

Middle Pett Farm

When strawberries were planted on 12 July 2012, the previously grubbed crop was still present with a high incidence of powdery mildew. For the IPDM mildew programme, five sprays of sulphur and potassium bicarbonate were applied and one spray of Prestop for botrytis. Nine sprays were applied for mildew control on the grower plot + 4 sprays for botrytis. The main disease problem was mildew due to high inoculum, inadequate spray cover and favourable weather. There was no difference between the IPDM and GS tunnels (Table 7.2.8).

Table 7.2.8. Incidence of powdery mildew (% leaf area mildewed) on Strawberry cvs. Elsanta (Middle Pett Farm) and Amesti (Manor Farm) in 2012

Site	Grower plot	IPDM plot
Middle Pett (11 Sep)	29.4	31.8
Manor Farm (30 Oct)	1.1	4.0

7.2.4. Management of botrytis

Tuesley Farm

Botrytis control in the IPDM tunnel was carried out using bumble bee vectored *Gliocladium catenulatum* (Prestop Mix) dispersed from a dispenser in the exit channel from the hive. Table 7.2.9 shows the amount of Prestop Mix added and dispersed from the hive over the season in the IPDM area. Over the duration of flowering nearly 60 g was dispersed to flowers, which equates to approximately 960 g per ha over a nine week period. In comparison, the Grower Standard monitoring tunnels received 10 botrytis fungicides in this same period. The botrytis untreated tunnel received no fungicides with botrytis activity.

Table 7.2.9. Prestop Mix dispersed by bees – Tuesley Farm 2012

Date	Prestop Mix introduced (g)	Prestop Mix remaining in hive (g)	Prestop Mix dispersed (g)
27.03.12	8.5		
02.04.12	8.5	5	3.5
07.04.12	8.5	4	4.5
11.04.12	8.5	5	3.5
16.04.12	8.5	5	3.5
21.04.12	8.5	4	4.5
26.04.12	8.5	4	4.5
01.05.12	8.5	3	5.5
06.05.12	8.5	5	3.5
11.05.12	8.5	5	3.5
16.05.12	8.5	4	4.5
21.05.12	8.5	6	2.5
26.05.12	8.5	4	4.5
31.05.12	8.5	4	4.5
05.06.12	8.5	5	3.5
11.06.12		5	3.5
TOTALS	119	68	59.5

To assess whether or not the Prestop Mix was being dispersed by the bees to flowers, 15 flowers were sampled from the IPDM, GS and BOT UT tunnels on three occasions and placed in damp chambers for assessment after seven and 14 days for botrytis levels and other fungal growth. It was not possible to detect *Gliocladium catenulatum* on any sampled flowers from the IPDM tunnels. Levels of flower botrytis were variable and showed no consistent differences between treatment tunnels. One sample of 10 flowers was sent to Verdera Oy (Prestop Mix producers) but again it was not possible to detect *Gliocladium* on flower parts. A bee was captured on leaving the hive and *Gliocladium* was successfully isolated from both the body and legs of the bee.

As it was not possible to detect *Gliocladium* on the flowers a UV tracer powder was introduced to a dispenser in the GS control hive; 26% of flowers collected after four hours and 40% of flowers after a week had UV powder present.

Some flower inoculation trials were also carried out by artificially introducing Prestop Mix to sampled flowers with a paint brush. All of the inoculated flowers showed *Gliocladium catenulatum* growing actively over the centres on the flowers and the calyx and there was a much reduced level of botrytis when compared to uninoculated control flowers. This demonstrates that *Gliocladium catenulatum* does establish on strawberry flowers and actively competes with botrytis.

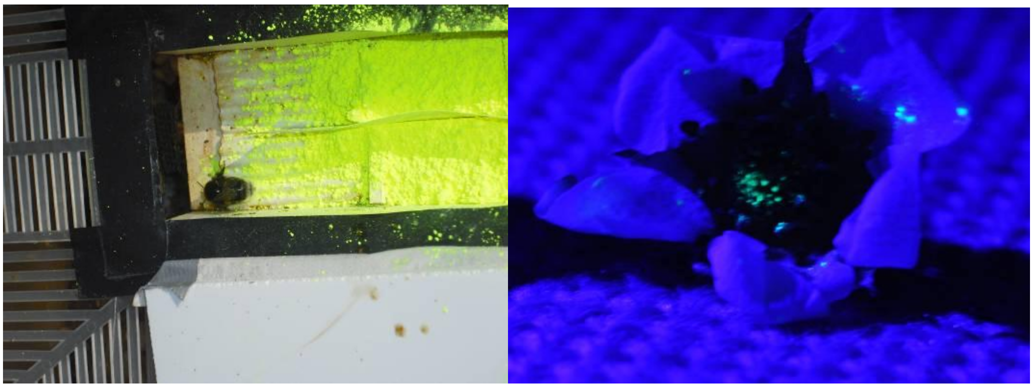

Figure 7.2.10. Bee exiting through hive dispenser filled with UV tracer powder. Flower under a black light to show UV powder vectored by bees – Tuesley Farm 2012.

Fruit was sampled on three occasions through harvest taking a random sample of fruit from the commercially picked trays for each monitoring tunnel. At picks two and three an extra GS tunnel was included from the same block of beds as the IPDM as there was a concern that the distance between the original GS and the IPDM tunnels might be causing a bigger difference because of their locations than any treatment effect. The GS tunnel was down a slope and appeared wetter under foot than the IPDM area at the top of the slope.

Fruit was stored under both ambient and cool conditions (<4^{o}C). The ambient fruit was assessed at three and seven days. At three days (Table 7.2.10) picks one and three showed no significant difference in levels of marketable fruit and fruit with botrytis between any of the monitored tunnels. At pick two the botrytis untreated tunnel showed significantly more botrytis and less marketable fruit compared to both the Grower Standard and IPDM tunnels.

At the seven day ambient fruit assessment (Table 7.2.11) picks 1 and 2 showed significantly less botrytis in the IPDM tunnels than in the GS tunnel. At pick 3 the botrytis untreated tunnel showed lower botrytis than all the other treatments.

The cold stored fruit samples were only assessed on day 7 (Table 7.2.12), and the IPDM treatment had as low (pick 2) or lower (pick 3) botrytis incidence than the GS treatment. The IPDM had a highly significantly lower proportion of fruit with botrytis than the tunnel which did not receive botrytis fungicides.

Table 7.2.10. Percentage of fruit stored under ambient conditions showing rots - 3 day assessment carried out on three occasions through harvest – Tuesley Farm 2012

Pick 1	**% Marketable**	**% Botrytis**	**% Mucor**	**% Penicillium**	**% Other fungi**
BOT UT	0.0	16.9	68.5	0.0	6.2
GS	0.0	33.9	29.7	18.6	51.7
IPDM	0.9	18.6	57.5	22.1	9.7
P. Value	ns (0.405)	ns (0.280)	0.002	0.004	<0.001
LSD (9 df)	1.65	17.34	22.97	10.94	15.48
Pick 2					
BOT UT	77.5	14.5	0.5	2.5	0.5
GS	88.0	8.5	0.5	2.0	1.0
GS extra	89.5	6.0	0.0	2.0	1.0
IPDM	93.5	2.5	0.5	0.5	0.0
P. Value	0.012	0.019	ns (0.802)	ns (0.639)	ns (0.426)
LSD (12 df)	8.91	7.02	1.33	3.50	1.48
Pick 3					
BOT UT	7.0	38.0	76.0	0.5	0.0
GS	18.0	25.0	50.0	5.5	0.0
GS extra	19.5	6.8	13.5	2.5	2.5
IPDM	28.5	15.3	30.5	5.0	1.0
P. Value	ns (0.108)	ns (0.742)	<0.001	ns (0.331)	0.146
LSD (12 df)	17.12	8.78	18.17	6.37	2.47

Table 7.2.11. Percentage of fruit stored under ambient conditions showing rots - 7 day assessment carried out on three occasions through harvest – Tuesley Farm 2012

Pick 1	% Marketable	% Botrytis	% Mucor	% Penicillium	% Other fungi
BOT UT	0.0	14.8	60.1	5.4	0.0
GS	0.0	25.7	22.5	39.2	14.1
IPDM	0.0	15.7	48.7	8.2	18.7
P. Value	-	<0.001	0.001	0.033	<0.001
LSD (9 df)	-	12.80	17.64	23.46	17.46
Pick 2					
BOT UT	2.0	92.5	67.0	14.0	4.5
GS	9.5	83.5	44.0	24.0	7.0
GS extra	4.5	91.0	60.0	25.0	4.5
IPDM	21.0	71.5	41.0	11.0	0.5
P. Value	0.019	0.032	0.028	0.003	ns (0.221)
LSD (12 df)	11.75	14.54	18.57	7.32	6.37
Pick 3					
BOT UT	0.0	37.5	89.5	2.0	3.0
GS	1.5	61.0	77.5	1.5	6.0
GS extra	2.5	80.5	52.5	13.5	5.5
IPDM	0.5	80.5	50.0	8.5	6.5
P. Value	ns (0.412)	<0.001	0.005	0.004	0.541
LSD (12 df)	3.36	15.89	22.01	6.31	5.52

Table 7.2.12. Percentage of fruit stored in cold store for three days followed by ambient conditions for four days showing rots - 7 day assessment carried out on three occasions through harvest – Tuesley Farm 2012

Pick 1	% Marketable	% Botrytis	% Mucor	% Penicillium	% Other fungi
BOT UT	11.9	42.4	0.0	3.4	8.5
GS	49.2	6.6	0.0	6.6	4.9
IPDM	52.5	13.1	0.0	4.9	4.9
P. Value	0.022	<0.001	-	ns (0.606)	ns (0.734)
LSD (9 df)	24.47	4.19	-	9.43	13.94
Pick 2					
BOT UT	17.5	74.5	13.5	27.0	15.5
GS	45.5	39.0	3.0	14.0	6.0
GS extra	65.5	22.5	0.5	4.5	2.0
IPDM	68.5	20.5	1.0	5.0	3.0
P. Value	<0.001	<0.001	<0.001	<0.001	0.001
LSD (12 df)	16.95	19.63	3.50	7.69	5.88
Pick 3					
BOT UT	5.5	38.5	57.0	6.0	0.0
GS	5.0	49.0	25.5	2.5	3.5
GS extra	8.0	45.0	16.5	2.0	3.0
IPDM	15.5	28.0	9.0	7.5	9.5
P. Value	ns (0.238)	0.045	<0.001	0.078	0.204
LSD (12 df)	11.75	14.85	10.58	4.83	4.21

Manor Farm

Flowering started on 1 June and bees were ordered for the crop. However, flowering stopped so the bees were cancelled. Flowering started again on 5 July and on 9 July bees were installed with Prestop Mix but performed poorly. New bees were introduced on 23 August. These were much more vigorous in Prestop delivery.

Up to 8 June the same programme was used in IPDM as in Grower Standard plots. After this the IPDM plots received one spray of Serenade ASO (*Bacilus subtilis*) and bee vectored Prestop Mix (*Gliocladium catenulatum*). The Grower Standard plot used four fungicide applications against botrytis.

After seven days ambient incubation, fruit had moderate level of botrytis (Table 7.2.13). Fruit picked on 11 and 28 September did not receive sprays for botrytis during flowering in the Grower Standard plot. Botrytis rot levels were similar in the Grower and IPDM plots on 11 September but less botrytis was present in the IPDM plot on 28 September. Mucor incidence was similar. Botrytis incidence in cold-stored fruit was less than in ambient fruit (Table 7.2.14).

Table 7.2.13. Incidence of rots in strawberry cv. Amesti in post-harvest tests following IPDM or Grower Standard P&D control programmes and 7 days incubation at ambient in 2012 at Manor Farm, Kent

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	28 August	3 day	0.9	0.0	5.6	0.3	6.8
		7 day	39.7	2.5	59.4	0.0	94.7
Grower	28 August	3 day	1.3	0.0	26.9	0.0	28.2
		7 day	26.3	0.0	74.4	0.0	97.2
IPDM	11 September	3 day	0.6	0.0	21.3	0.3	21.9
		7 day	18.4	0.0	74.4	0.9	94.1
Grower	11 September	3 day	0.3	1.3	24.1	1.6	26.9
		7 day	16.3	1.3	74.4	3.4	92.8
IPDM	28 September	3 day	-	-	-	-	-

		7 day	17.5	0.0	77.5	1.3	96.2
Grower	28 September	3 day	-	-	-	-	-
		7 day	40.4	0.0	56.7	0.0	97.1

Table 7.2.14. 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 temperature in 2012 at Manor Farm, Kent

Treatment	Sample date	Assessment	% Rotted fruit					
			% Botrytis	% Penicillium	% Mucor	% Mildew	% Other rot	% Total rot
IPDM	28 August	3 day	0.0	0.0	0.0	5.9	0.0	5.9
		7 day	11.9	0.0	48.4	-	0.0	60.1
Grower	28 August	3 day	0.3	0.0	0.3	0.0	0.0	0.6
		7 day	35.1	0.0	19.5	-	0.0	54.3
IPDM	11 September	3 day	0.3	0.0	0.0	11.4	0.0	11.7
		7 day	8.1	0.0	19.2	15.7	0.8	43.8
Grower	11 September	3 day	0.0	0.0	0.0	13.8	0.0	13.8
		7 day	17.0	0.0	15.1	18.1	1.6	51.8
IPDM	28 September	3 day	5.7	0.0	0.0	9.1	0.3	15.1
		7 day	23.4	1.7	4.6	13.4	1.1	44.2
Grower		3 day	3.2	0.0	0.9	8.1	0.0	12.2
		7 day	13.5	3.2	4.6	13.3	0.9	35.5

Middle Pett Farm

Up to 22 August the same spray programme for botrytis was applied in the IPDM as in the grower plot. After this date the BOTEM model was used to trigger spray applications of Prestop (*Gliocladium catenulatum*). Botrytis and mucor rot incidence were similar on IPDM and grower plots. Incidence of rots was lower in fruit that had been cold-stored for three days (Table 7.2.15 and Table 7.2.16).

Table 7.2.15. Incidence of rots in strawberry cv. Elsanta in post-harvest tests following IPDM or grower P&D control programmes and 7 days incubation at ambient temperature in 2012 at Middle Pett Farm

Treatment	Sample date	Assessment	% Rotted fruit				
			% Botrytis	% Penicillium	% Mucor	% Other rot	% Total rot
IPDM	12 September	3 day	0.0	0.0	0.0	0.0	0.0
		7 day	13.4	3.8	18.4	7.5	40.9
Grower	12 September	3 day	0.0	0.0	0.0	0.0	0.0
		7 day	10.3	5.6	18.8	5.9	38.7
IPDM	20 Sep	3 day	0.0	0.0	0.0	0.0	0.0
		7 day	19.4	0.3	1.9	1.6	23.2
Grower	20 Sep	3 day	0.0	0.0	0.0	0.0	0.0
		7 day	12.2	0.0	4.1	2.8	19.1
IPDM	28 Sep	3 day	-	-	-	-	-
		7 day	55.0	0.0	35.0	2.0	92.0
Grower	28 Sep	3 day	-	-	-	-	-
		7 day	53.3	0.0	24.2	1.7	79.2

Table 7.2.16. Incidence of rots in strawberry cv Elsanta in post-harvest tests following IPDM or grower P&D control programmes and three days at low temperature storage and four days at ambient temperature in 2012 at Middle Pett Farm

Treatment	Sample date	Assessment	% Rotted fruit					
			% Botrytis	% Penicillium	% Mucor	% Mildew	% Other rot	% Total rot
IPDM	12 Sep	3 day	0.0	0.0	0.0	0.0	0.0	0.0
		7 day	2.4	0.0	7.6	1.0	0.0	11.0
Grower	12 Sep	3 day	0.0	0.0	0.0	0.0	0.0	0.0
		7 day	2.9	0.0	6.9	2.6	0.2	12.6
IPDM	20 Sep	3 day	0.0	0.0	0.0	-	0.0	0.0
		7 day	0.6	0.0	0.0	-	0.5	1.1
Grower	20 Sep	3 day	0.0	0.0	0.0	-	0.0	0.0
		7 day	0.7	0.0	0.3	-	1.2	2.2
IPDM	28 Sep	3 day	1.1	0.0	0.0	100.0	0.0	100.0
		7 day	17.4	0.7	0.0	100.0	2.6	100.0
Grower	28 Sep	3 day	0.5	0.0	0.0	1.2	0.0	1.7
		7 day	11.3	1.8	0.0	2.2	0.7	16.0

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

Tuesley Farm

Yield and class (Class 1 or waste) was recorded by the farm staff in the three monitoring tunnels, and for the whole field. Total yield (i.e. Class 1 and waste) was higher in the GS and botrytis untreated (BOT UT) tunnel compared with the IPDM (Table 7.2.17). GS and BOT UT were in the lower section of the field and were more vigorous and within a slightly more sheltered area and so environmental factors may account for this yield variation. However, the IPDM tunnel had a much higher percentage of Class 1 fruit (79 %) compared with the GS (56 %) and the BOT UT (49%), resulting in almost identical marketable yields (600 kg) from the IPDM and Grower Standard tunnels There was an average 76% Class 1 fruit across the field as a whole.

Table 7.2.18 shows the reasons for fruit being classed by the farm staff as waste, this was mainly a result of misshapen and cat-faced berries, most probably a result of the cold wet weather experienced this year. The other main cause of discarded fruit was botrytis. Levels of botrytis and other rots were generally higher in the botrytis untreated tunnel and Grower Standard.

Causes of waste in the IPDM tunnel were similar to the GS tunnels except for a higher incidence of slug damage at pick 2 and a higher incidence of mis-shapes at pick 3. Slug pellets as Sluxx (ferric phosphate) were applied to the GS only in error.

Table 7.2.17. Yield in kg recorded throughout harvest for ~70 m tunnel – Tuesley Farm 2012. Yield records omitted from 9 May due to discrepancy in BOT UT and Grower Standard yield recorded

	IPDM			Grower Standard			BOT UT		
	Class 1	Waste	% Class 1	Class 1	Waste	% Class 1	Class 1	Waste	% Class 1
05-May	3.2	0.8	80.0				2.8	5.6	33.3
09-May									
13-May	6.0	2.4	71.4	22.4	12.5	64.2	10.8	12.5	46.4
16-May	11.1	15.0	42.5	20.3	10.0	66.9	13.5	40.0	25.2
19-May	5.9	2.0	74.3	22.1	25.0	46.9	18.5	40.0	31.6
23-May	18.0	3.2	85.1	22.0	100.0	18.0	21.0	100.0	17.4
26-May	137.4	12.5	91.7	168.0	50.0	77.1	128.0	100.0	56.1
31-May	260.0	50.0	83.9	196.0	125.0	61.1	208.0	100.0	67.5
04-Jun	160.0	75.0	68.1	152.0	150.0	50.3	116.0	150.0	43.6
TOTALS	601.6	160.9	78.9	602.7	472.5	56.1	518.6	548.1	48.6

Table 7.2.18. Waste fruit analysis on three occasions through harvest showing % fruit in each category – Tuesley Farm 2012

	% Catlip/ Miss-haped	% Botrytis	% Penicillium	% Mucor	% Other rot	% Overripe	% Sun damage	% Slug damage
Pick 1 Bulked sample	26	36	-	-	6	12	10	4
Pick 2								
Bot UT	24	34	10	6	22	38	8	4
GS	36	32	2	0	10	32	8	4
GS extra	42	18	4	2	12	36	4	6
IPDM	20	14	2	4	6	34	6	20
Pick 3								
Bot UT	44	38	0	0	0	14	2	20
GS	38	32	2	0	0	18	2	6
GS	36	28	0	0	0	32	0	6

extra IPDM	58	24	0	0	0	14	0	2

Residue analysis was carried out on three occasions. Most of the pesticides detected in the IPDM tunnel were in the 9 May sample and resulted from the application of Fortress (quinoxyfen) on 22 March. Other actives detected at this stage could have resulted from drift from the surrounding GS areas, these actives that were not directly applied to the IPDM, were in the main found at lower levels than the GS samples where applications included Switch, (cyprodinil) on 22 March, Scala (pyrimethanil) on 10 April, Teldor (Fenhexamid) on 26 April, Signum (boscalid and pyraclostrobin) on 1 May and Rovral (idoprione) on 9 May). Only thiacloprid residues were detected in the IPDM tunnel in the second and third fruit samples. This followed a single application of Calypso on 26 April to bring the aphid population under control. All levels were below the MRL.

With the exception of aphid control, the equivalent crop pest and disease management and fruit quality was achieved using non-pesticidal methods in the IPDM tunnel. This resulted in fewer pesticide applications and a reduction in detection of pesticide residues (at any level above zero) by around 75%. The total numbers of pesticide residues detected over the three samples were 35, 21 and 9 in the GS, Bot UT and IPDM respectively.

Table 7.2.19. Residues (mg/kg) found in three different management regime tunnels - first fruit sample taken on 18 May – Tuesley Farm 2012

Active	GS	IPDM	BOT UT
Azoxystrobin	0.10	ND	0.1
Boscalid	0.14	0.01	0.01
Cyprodinil	0.10	0.02	0.01
Fludioxonil	0.07	ND	ND
Iprodione	0.19	0.02	0.02
Kresoxim methyl	0.01	ND	0.01
Myclobutanil	0.05	ND	0.02
Pyraclostrobin	0.05	ND	ND
Pyrimethanil	0.45	0.05	0.08
Quinoxyfen	0.01	0.01	ND
Fenhexamid	0.16	0.01	0.04
Pirimicarb	0.06	ND	0.02
Thiacloprid	0.04	0.04	0.03

Table 7.2.20. Residues (mg/kg) found in the three different management regime tunnels - second fruit sample taken on 27 May – Tuesley Farm 2012

Active	GS	IPDM	BOT UT
Azoxystrobin	0.02	ND	0.04
Boscalid	0.07	ND	ND

Bupirimate	0.06	ND	ND
Cyprodinil	0.04	ND	ND
Fludioxonil	0.03	ND	ND
Iprodione	0.12	ND	0.01
Myclobutanil	0.02	ND	0.01
Pirimicarb	0.04	ND	0.03
Pyraclostrobin	0.01	ND	ND
Pyrimethanil	0.27	ND	0.02
Fenhexamid	0.43	ND	0.01
Thiacloprid	0.04	0.04	0.02

Table 7.2.21. Residues (mg/kg) in third fruit sample taken on 12 June – Tuesley 2012

Active	GS	IPDM	BOT UT
Azoxystrobin	0.01	ND	ND
Boscalid	0.04	ND	ND
Bupirimate	0.01	ND	ND
Cyprodinil	0.02	ND	ND
Fludioxonil	0.02	ND	ND
Iprodione	0.10	ND	0.01
Myclobutanil	0.01	ND	ND
Pyrimethanil	0.17	ND	0.01
Fenhexamid	0.24	ND	0.03
Thiacloprid	0.01	0.01	0.01

ND – none detected

Manor Farm

At Manor Farm only Class 1 fruit was recorded; Class 2 fruit was discarded as waste. The first recorded pick was on 3 July and the last on 28 September, with a total of 18 picks. The total yield per acre for the IPDM plot was 6.03 t and for the Grower Standard was 8.19 t. Reasons for downgrading of fruit at harvest are shown in Table 7.2.22. Mis-shapes, possibly caused by capsid feeding, were higher in the IPDM plot than the Grower Standard plot, as was mildew damage. Botrytis levels were higher in the Grower Standard than the IPDM plot, as was mucor/rhizopus in the first pick.

Table 7.2.22. Percentage damage in waste fruit from two picks at Manor Farm 2012.

	Mis-shapes	Mildew	Botrytis	Mucor/ rhizopus	Other rots	Over/ uneven ripeness	Small	Slugs	Surface grazing
1 IPDM	25	43	0.9	2.9	0	8.6	13.2	0	0
1 GS	13.9	15.7	5.9	15.7	0	27.2	19.3	0	5.1
2 IPDM	13.1	58.6	2.6	0	1.2	9	5.8	9.6	0
2 GS	3.3	39.3	7.9	0	1.3	26	7.7	4.3	0

On 29 August the same three pesticide residues were detected in fruit from the IPDM and the Grower Standard tunnels. On 1 October, there was one pesticide residue detected in

fruit from the IPDM tunnel and seven from the GS tunnel. All residues detected were below the MRL values. None of the three pesticide residues detected in the IPDM plot were of pesticides applied to the crop. Investigations into possible reasons for their presence were inconclusive.

Table 7.2.23. Residues detected on fruit picked on two occasions at Manor Farm, Kent in 2012 and the maximum residue levels (MRLs) permitted

		Manor Farm			
	MRL	Residue levels for IPDM and Grower tunnels (mg/kg)			
	mg/kg	29 August		1 October	
Chemical		IPDM	Grower	IPDM	Grower
azoxystrobin	10.0	0.029	0.076	ND	0.01
boscalid	10.0	ND	ND	ND	0.16
bupirimate	1.0	ND	ND	ND	0.23
myclobutanil	1.0	ND	ND	ND	0.013
penconazole	0.5	0.017	0.042	ND	ND
pyraclostrobin	1.0	ND	ND	ND	0.034
pyrimethanil	5.0	ND	ND	0.011	0.45
spinosad	0.3	0.023	0.056	ND	ND
thiacloprid	1.0	ND	ND	ND	0.021

Middle Pett Farm

Yield from Middle Pett Farm is shown in Table 7.2.24. In the first three picks yield was similar in the IPDM and Grower Standard plots. After that mildew became a serious problem in the IPDM plot and the picked fruit was downgraded to waste (Table 7.2.24). It was later established that the probable cause of this high infection was due to poor spray coverage with the spraying equipment used; this was demonstrated at a consortium farm walk at this site.

Table 7.2.24. Yield from Middle Pett Farm, 2012. Data were collected from three tunnels in each treatment = a total of 8,160 plants for each plot. * mildew became very bad from here onwards

	IPDM (kgs)			Grower Standard (kgs)		
Date	Class 1	Class 2	Waste	Class 1	Class 2	Waste
08-Sep	153	0	1.2	106	0	5.8
12-Sep	316	0	11.2	303	0	12.6
16-Sep	404	0	36.4	401	0	6.2
20-Sep	167	0	345	442	0	6.1
24-Sep	105	0	401	431	0	17.4
28-Sep	66	0	433	509	0	27.6
03-Oct	*	0	321	412	0	16.2
08-Oct	0	0	351	418	0	8.5
13-Oct	0	0	278	378	0	19.8
18-Oct	0	0	235	219	0	19.6
Totals	1211	0	2,413	3,619	0	140

Reasons for downgrading fruit at harvest are shown in Table 7.2.25. Mildew levels were high in this planting, especially in the IPDM plot. There were no other differences between the two treatments. The initial high level of mis-shapes was not due to pest feeding as no pests were recorded on this planting.

Table 7.2.25. Percentage damage in waste fruit from two picks at Middle Pett Farm 2012.

	Mis-shapes	Mildew	Botrytis	Mucor/ rhizopus	Other rots	Over/ uneven ripeness	Small	Crack ing	Surface grazing
1 IPDM	40	13	2	0.5	0.2	25	20	0	0
1 GS	47	0	3.3	0.2	0.4	27	22	0	0
2 IPDM	7	21	0.1	0	0	25	18	10	17
2 GS	11	12	0.1	0	0	35	25	8	7

No residues were detected in fruit from the IPDM plot in September, compared with three in the GS plot, all at below MRL values (Table 7.2.26).

Table 7.2.26. Residues detected on fruit picked on two occasions at Middle Pett Farm, Kent in 2012 and the maximum residue levels (MRLs) permitted

		Middle Pett Farm			
	MRL	Residue levels for IPDM and Grower tunnels (mg/kg)			
	mg/kg	13 September		1 October	
Chemical		IPDM	Grower	IPDM	Grower
azoxystrobin	10.00	ND	ND	0.086	0.280
boscalid	10.00	ND	ND	0.010	0.041
bupirimate	1.00	ND	0.021	0.030	0.330

iprodione	15.00	ND	0.280	0.290	0.099
mepanipyrim	2.00	ND	ND	0.015	0.061
myclobutanil	1.00	ND	0.018	0.044	0.170
pyrimethanil	5.00	ND	ND	0.130	0.410

Conclusions

Tuesley Farm conclusions

- Aphid control was not achieved with Aphidsure fragaria in 2012, with few mummies found, probably because of unusually low temperatures in the spring and insufficient or delayed release timings;

- TSSM and tarsonemid numbers were lower in IPDM tunnels than the Grower Standard management tunnels;

- Other pests were at a very low level;

- Powdery mildew was kept under control by using computer model alerts based on site temperature and humidity records and field observations to trigger potassium bicarbonate application;

- Neither fungicides nor Prestop Mix gave complete control of latent botrytis in fruit;

- Prestop Mix biofungicide dispersed by bees achieved equivalent levels of botrytis in stored fruit compared with those following a standard fungicide programme;

- The untreated tunnel area had worse botrytis incidence in stored fruit than tunnels where either Prestop Mix or fungicide sprays were used;

- The IPDM programme achieved equivalent Class 1 yield, but there was a lower total yield (which might relate to tunnel position)

- Around 75% fewer pesticide active ingredient residues were found in IPDM fruit compared with conventional fruit, with only one chemical found in the IPDM in each of two picks;

- The deployment of some IPDM measures and monitoring was carried out by the Tuesley Farm staff, showing that these could be incorporated into the farm's routine crop inspection visits.

Manor Farm conclusions

- The use of trap crop and bug vaccing was not able to prevent populations of *L. rugulipennis* from building up to damaging levels and a pesticide had to be applied to reduce numbers;

- The IPDM plot had lower numbers of strawberry blossom weevil overall than the Grower Standard plot;

- Thrips numbers were higher in the IPDM plot than the Grower Standard but no fruit damage was seen in either plot;

- Numbers of aphids decreased in early August in the IPDM plot, while in the Grower Standard numbers increased;

- No tarsonemid mites were recorded from either plot;

- Spider mite numbers were lower in the IPDM plot than in the Grower Standard throughout the season;

- These results show that in the IPDM plots control of SBW, aphids and spider mite was as good as, if not better than, in the Grower Standard plot;

- Control of capsids and thrips was not as effective in the IPDM plot;

- More frequent bug vaccing may be needed to control capsid numbers in the IPDM plot;

- Seven day ambient fruit had moderate level of botrytis;

- Botrytis rot levels were similar in Grower Standard and IPDM plots on 11 September but there was less botrytis in the IPDM plot on 28 September;

- Botrytis incidence in cold-stored fruit was less than in ambient fruit;

- Mucor incidence was similar in both plots.

Middle Pett Farm conclusions

- No differences were seen in pest numbers in the IPDM or Grower Standard plots at this site;

- The main disease problem was mildew due to high inoculum, inadequate spray coverage and favourable weather;

- Botrytis and mucor rot incidence were similar on IPDM and Grower Standard plots;

- Incidence of rots was lower in fruit that had been cold-stored for three days.

Overall conclusions

Treatment comparisons in three commercial tunnel strawberry crops in 2011 and 2012 support the use of IPDM to manage pests and diseases. The use of the IPDM strategies used appeared to be as effective as the host grower's standard practices in controlling the key strawberry pests and diseases. This was achieved with many fewer detections of pesticide residues in fruit.

IPDM components need to be tailored to individual crop and site risk; treatments need to be adjusted according to season, the results of ongoing monitoring of ongoing crop pests, pathogens and damage and of weather conditions favourable to disease. Overall it appears for early and mid season June bearer crops with close monitoring and attention to detail these strategies can be implemented very successfully without any detriment to yield and quality and with far fewer detectable chemical residues. However as the season progresses with ever bearer crops the pest and disease pressure can build rapidly and frequent monitoring is required.

The specific components of IPDM found to be useful in replicated trials in earlier work within this project (or that appear to be useful in the un-replicated field comparisons in 2011 and 2012 or other relevant work being carried out in the wider industry) are listed below (Table

7.2.27), together with an assessment of the strength of evidence supporting their effectiveness and some potential positive and negative side effects

Table 7.2.27. Summary of IPDM strategies implemented over three sites in both 2011 and 2012 (five locations overall, six harvested crops) with their potential for success and details for considerations

Pest or disease and IPDM component	Additional HDC project work supporting	No. crops tested on	Evidence of effectiveness	Positive side effects	Negative side effects /considerations
Botrytis					
BOTEM disease prediction model	SF 47	6	Medium	Avoids unnecessary sprays	Relies on well placed loggers within the crop – potential for wide spatial variation. Early covered only - Risky for late season and EB
Bee vectored Prestop Mix – *Gliocladium catenulatum*		4	Mixed	Low risk of resistance, avoids sprays during flowering no MRL	Uncertainty over UK approval for this method.
Spray applied Prestop /Serenade ASO		4	Low	Low risk of resistance, no MRL	Tighter environmental limits for efficacy. ££
Cool storage – field heat removal			High	Reduces post harvest rot development	Energy cost
Powdery mildew					
Basic substances (potassium bicarbonate, sulphur)	SF 113	6	High	Low resistance risk	Can harden foliage and reduce vigour. Coverage key good application essential
Forecast disease risk		6	Medium	Aids spray timing and avoids unnecessary sprays	Relies on well placed loggers within the crop – potential for wide spatial variation. Not suitable for varieties prone to flower and fruit infection at this stage. Use for early crop, low

Pest or disease and IPDM component	Additional HDC project work supporting	No. crops tested on	Evidence of effectiveness	Positive side effects	Negative side effects /considerations
					inoculum. Not suitable for late season high inoculum susceptible varieties
Tunnel ventilation	SF 113		Medium /high	Reduce botrytis and other diseases	Labour costs. Not good uptake by industry
Resistant/ tolerant varieties			High		
Blackspot – Colletotrichum acutatum					
Straw alley ways		4	Inconclusive	Hygiene – suppress infection from water splash. Suppresses other water splash diseases - botrytis	
Routine application of Signum pre flowering			Inconclusive	Reduce inoculum – pre flowering therefore unlikely to leave a residue	
Disease general					
Crop hygiene – fruit removal, cleaning up plant material		4	High	Improved spray coverage, reduce inoculum	Labour
Aphids					
Autumn clean up Calypso applications	First 3 years	1	High	Reduces overwintering populations. Application does not result in residues	Compatibility with broad spec insecticides
Aphidsure		6	Medium	Attacks all the	Relies on careful

Pest or disease and IPDM component	Additional HDC project work supporting	No. crops tested on	Evidence of effectiveness	Positive side effects	Negative side effects /considerations
fragaria - mix of 6 parasitoid wasps. 3 x 3 weeks apart -1 tube/200m^3				most common aphid species, no risk of resistance developing	timing, and monitoring £££.
Strawberry blossom weevil					
Grid of white cross vane Super traps and lures for monitoring – 36/ha	First three years	6	Medium (low levels in trials	Avoids unnecessary sprays harmful to introduced Predators	Labour, upkeep and monitoring
Two spotted spider mites					
Phytoseilus persimilis introductions – 10/m^2 at first site of pest	Standard grower practice	6	High	Reduces spray requirements	Timing and regular monitoring important for success
Tarsonemid mites and thrips					
Amblysieus cucumeris sachet introductions – 1/2m	WFT LINK Standard grower practice	6	High	Reduces spray requirements. Generalist predator	Timing and regular monitoring important for success
Orius	WFT LINK	1	Low	Reduces spray requirements. Generalist predator	Timing, temperatures and regular monitoring important for success. Hard to establish. ££
Common green capsid and ETPB					
Lygus ruglipenis – green cross vane and lure monitoring traps	PC/SF 276	4	medium	Avoids unnecessary sprays harmful to introduced predators	Labour, upkeep and monitoring
Lygocoris	PC/SF 276	4	medium	Avoids	Labour, upkeep

Pest or disease and IPDM component	Additional HDC project work supporting	No. crops tested on	Evidence of effectiveness	Positive side effects	Negative side effects /considerations
pabulinus – blue sticky and lure lure monitoring traps				unnecessary sprays harmful to introduced predators	and monitoring
Bug vaccing - Repeated applications 1-2x per week	Overseas support. Positive in first three years	2	Medium – low in LINK trails	Reduces sprays	Unspecific, labour and fuel costs. Set up critical.
Alyssum trap plants	Early work showed v attractive.	2	Low in LINK trails	Focus for monitoring – targeted spray applications	Establishment of plants variable. Have to time carefully to match flower timing. £££ compared with benefits
Earwigs					
Glue barrier traps to table top leg structures		2	Mixed	Reduced need to spray pest	Labour cost, careful application v important and required refreshment, and get in early
Tortrix monitoring					
Delta traps and lures	Commercially available	2	Medium	Focus for monitoring – spray applications only if required	Labour cost for monitoring, just 3 species, Thresholds need developing

Financial appraisal

Table 7.2.25 shows a financial breakdown per target for control measures recommended as part of IPDM programmes in the three protected strawberry cropping systems used in the final year of this project. The IPDM strategies gave an overall increase in the cost of managing strawberries because of some higher material costs and longer staff time in the crop tending traps and data loggers and replenishing fungal and arthropod biocontrol agents. However, equivalent yields and fruit quality were obtained using IPDM as in conventionally managed crops, and with fewer residue traces.

Individually, certain strategies represented a saving; for example the potential to reduce the number of sprays by using the powdery mildew and the botrytis forecasting models to time applications of fungicides and commodity substances rather than relying on a programme of weekly sprays. The use of bees to vector the biofungicide Prestop Mix (under Extrapolated Experimental Approval) represented a small increase in the cost of botrytis control (£115 per hectare), but without the risk of pesticide residues.

Trap monitoring was relatively cost effective as knowledge of low populations reduced pesticide applications (and hence potential residues) for European tarnished plant bug, common green capsid and strawberry blossom weevil.

The use of preventive introductions of the aphid parasitoid mixture was considerably more expensive than that of an aphicide, although a relatively cheap single parasitoid species product could be used instead where the aphid species is known. Conventionally grown crops usually utilise biocontrol agents against two-spotted spider mites, western flower thrips and tarsonemids, however the earlier introduction of biocontrols at higher numbers in the IPDM programme gave better, although more costly, control.

Crop hygiene measures such as autumn fungicide and insecticide sprays and debris removal were emphasised within the IPDM program. The adoption of other IPDM strategies will need to be tailored to the site and cropping situation, selecting the most appropriate strategies according to particular pest pressures in that locality and population changes as the season progresses.

Table7.2.25. Financial appraisal of IPDM programmes, based on programmes implemented at the three trial sites in 2012 to show the optimal IPDM strategies for a main season, 60 day and everbearer crop compared with a standard commercial program. All values are per hectare excluding VAT, and include plant protection products, staff time, trapping systems and other sundries.

	Main season June bearer – soil grown			**60 day June bearer – table top in coir**		
Target	**Typical programme**	**IPDM**	**Additional Cost/ha**	**Typical programme**	**IPDM**	**Additional Cost/ha**
Botrytis	4 fungicides; 1 pre-flowering; 3 at 7-10 day intervals through flowering	1 fungicide pre-flowering; Bumble bee dispersed biofungicide Prestop Mix through flowering *(Bee dispersal not yet approved in UK)*		3 fungicides: 1 pre- flowering, then 2 at 7-10 day intervals from 5 % flower	1 fungicide pre-flowering, then timed applications of fungicide - according to BOTEM model and field observations	Very low risk of fruit loss to this disease *Variable; 2012 estimate
	£ 361	£ 476	£ 115	£ 270	£ 266 *	- £ 4
Powdery mildew	ProgramME of up to 7 fungicides with additional potassium bicarbonate and sulphur applications during harvest	Fungicide, potassium bicarbonate and sulphur applications timed according to forecasting model and field observations	*Variable depending on disease pressure - 2012 estimate	Programme of up to 7 fungicides with potassium bicarbonate and sulphur applications during harvest	Fungicide, potassium bicarbonate and sulphur applications timed according to forecasting model and field observations	*Variable depending on disease pressure; 2012 estimate
	£ 879	£ 475*	-£ 404	£ 866	£ 530*	- £ 336
Aphids	As required up to two applications of an aphicide	Calypso autumn clean up. Aphid parasitoid mix 1/200 m² on 3 occasions		*Low risk*	*Low risk*	Low risk
	£ 119	£ 1,850	£ 1,731			
Strawberry blossom weevil	*Low risk, but if pest observed;* application of a chlorpyrifos product	*Low risk, but if history/risk of pest then;* deploy 36 white cross vane traps and lures per ha.		*Low risk*	*Low risk*	Low risk
	£ 26	£ 475	£ 449			

	Main season June bearer – soil grown			60 day June bearer – table top in coir		
Target	**Typical programme**	**IPDM**	**Additional Cost/ha**	**Typical programme**	**IPDM**	**Additional Cost/ha**
Capsid	*If pest observed then;* application of a chlorpyrifos product	2 green cross vane bucket traps for European tarnished plant bug, and 2 blue sticky traps for Common green capsid per hectare		As main season if observed	As main season if observed	Low risk
	£ 26	£ 113	£ 86			
Two spotted spider mite	Up to 2 applications of an acaricide. *P. persimilis* introduction 25 K/ha 2 introductions at 2 week intervals at first sign of pest	High rate *P. persimilis* introduction at first sign of pest 100 K/ha, further release 25 K/ha based on monitoring success of predators		As main season if observed	As main season if observed	Low risk
	£ 774	£ 1,178	£ 404			
Tarsomemid and WFT	*If risk identified then;* *N. cucumeris* loose product as required. 50/m^2 on two occasions	*If risk identified then;* *N. cucumeris* slow release sachets, followed by loose product 50/m^2 as required		As main season if observed	As main season if observed	Low risk
	£519	£ 844	£ 325			
Earwigs	Not applicable	Not applicable		Insecticide application	Insect barrier glue on table top legs	
			n. a.	£ 82	£ 176	£ 94
Total	**£ 2,707**	**£ 5,414**	**£ 2,706**	**£ 1,219**	**£ 973**	**- £ 246**

Target	Everbearer – soil grown		
	Typical programme	**IPDM**	**Additional Cost/ha**
Botrytis	4 fungicides - 1 pre-flowering, 3 at 7-10 day intervals through flowering as required according to weather	1 fungicide pre-flowering – Bumble bee dispersed biofungicide Prestop Mix through flowering *(Bee dispersal not yet approved in UK)*	
	£ 416	£ 528	£ 112
Powdery mildew	Programme of up to 7 fungicides with potassium bicarbonate and sulphur applications during harvest	Fungicide, potassium bicarbonate and sulphur applications timed according to forecasting model and field observations	*Variable based on season and pressure; 2012 estimate - £ 331
	£ 974	£ 642	
Aphids	As required up to 3 applications of an aphicide	Aphid parasitoid mix 1/200m² on 3 occasions	
	£ 179	£ 1,873	£ 1,694
Strawberry blossom weevil	*If pest observed then;* application of a chlorpyrifos product	*Low risk, but if history/risk of pest then;* trapping as for main season crop	
	£ 26	£ 565	£ 538
Two spotted spider mite	Up to 2 applications of an acaricide. *P. persimilis* introduction 25K/ha 2 introductions at 2 week intervals at first sign of pest	High rate *P. persimilis* introduction at first sign of pest 100K/ha, a further release 25K/ha based on monitoring success of predators	
	£ 737	£ 1,179	£ 442
Capsids	*If pest observed then;* up to 2 insecticide applications	2 green cross vane bucket traps for European tarnished plant bugs, and 2 blue sticky traps for common green capsid per hectare	
	£ 86	£ 176	£ 90
Tarsom-emid and WFT	*If risk identified then;* *N. cucumeris* loose product as required. 50/m^2 on 4 occasions	*If risk identified then;* *N. cucumeris* slow release sachets, repeated after 6-8 weeks followed by loose product 50/m^2 as required	
	£ 1,327	£ 1,359	£ 32
Total	**£ 3,748**	**£ 6,324**	**£ 2,576**

Appendix 1. Spray programmes
Tuesley spray programmes detailed in Tuesley site summary Table 7.2.1.

Table Appendix 1.1. Spray applications 2012 Block 3 Manor Farm**;** sprays applied up to 25/09/12

IPDM plot

Date	Products	Rate/ha	Active ingredient
22-Apr	Fortress	0.25	Quinoxyfen
02-May	Stroby	0.3	Kresoxim-methyl
02-May	Lynx	15	Metaldehyde
14-May	Fortress	0.25	Quinoxyfen
20-May	Systhane	0.5	Myclobutanil
27-May	Stroby	0.3	
8-Jun	Serenade ASO	10 l/ha	*Bacillus subtilis*
	Sulphur	3 l/ha	
10-Jul	Potassium bicarbonate	5 kg/ha	
	Sulphur	1 kg/ha	
22-Jul	Sulphur	1 kg/ha	
07-Aug	Sulphur	1 kg/ha	
12-Aug	Sulphur	1 kg/ha	
22-Aug	Sulphur	1 kg/ha	
28-Aug	Chess	0.4 kg/ha	
04-Sept	Potassium bicarbonate	5 kg/ha	
	Sulphur	1 kg/ha	
10-Sept	Sulphur	1 kg/ha	
19-Sept	Sulphur	1 kg/ha	
25-Sept	Sulphur	1 kg/ha	

Grower Standard Plot

Date	Product	Rate/ha	Active Ingredient
22-Apr	Fortress	0.25	Quinoxyfen
02-May	Stroby	0.30	Kresoxim-methyl
02-May	Lynx	15.00	Metaldehyde
14-May	Fortress	0.25	
20-May	Systhane	0.50	Myclobutanil
27-May	Stroby	0.30	
05-Jun	Topas	0.50	Penconazole
	Chlorpyrifos	1.00	Chlorpyrifos
15-Jun	Systhane	0.50	
22-Jun	Amistar	1.00	Axoxystrobin
29-Jun	Systhane	0.50	
01-Jul	Potassium	5.00	

	bicarbonate		
05-Jul	Amistar	1.00	
10-Jul	Potassium bicarbonate	5.00	
	Sulphur	1.00	
16-Jul	Topas	0.25	
	Calypso	0.25	
	Rovral	0.40	
22-Jul	Potassium bicarbonate	5.00	
	Sulphur	1.00	
27-Jul	Potassium bicarbonate	5.00	
	Sulphur	1.00	
31-Jul	Systhane	0.50	Myclobutanil
	Masai	0.75	
	Borneo	0.17	Etoxazole
07-Aug	Potassium bicarbonate	5.00	
	Sulphur	1.00	
09-Aug	Amistar	1.00	
	Hallmark	0.08	
12-Aug	Potassium bicarbonate	5.00	
	Sulphur	1.00	
17-Aug	Kindred	0.60	Meptyldinocap
	Tracer	0.15	Spinosad
22-Aug	Potassium bicarbonate	5.00	
	Sulphur	1.00	
26-Aug	Topas	0.50	Penconazole
	Tracer	0.15	Spinosad
31-Aug	Systhane	0.50	
	Calypso	0.25	Thiacloprid
04-Sep	Potassium bicarbonate	5.00	
	Sulphur	1.00	
07-Sep	Nimrod	1.50	
	Tracer	0.15	
10-Sep	Potassium bicarbonate	5.00	
	Sulphur	1.00	
16-Sep	Signum	1.70	Boscalid, pyraclostrobin
19-Sep	Potassium bicarbonate	5.00	
	Sulphur	1.00	
24-Sep	Nimrod	1.50	Bupirimate
	Scala	2.00	Pyrimethanil

Table Appendix 1.2. Spray programme, Middle Pett, Store Field, cv. Elsanta

Treatment date	Area treated	Problem	Treatment details	Active	h/i
19-Jul	**incl. trials**	Phytophthora	Paraat @ 3.0kg per ha via dripper	Dimethomorph	35 days
26-Jul	**incl. Trials**	Mildew	Fortress @ 250ml in 1000l of water per ha	Quinoxyfen	14 days
		Botrytis	Rovral WG @ 1.0kg in 1000l of water per ha	Iprodione	2 days
		Foliar feed	Maxicrop Triple @ 4.0l in 1000l of water per ha	Seaweed extracts	0 days
01-Aug	**incl. Trials**	Mildew	Stroby WG @ 300g in 1000l of water per ha	Kresoxim-methyl	14 days
		Botrytis	Scala @ 2.0l in 1000l of water per ha	Pyrimethanil	3 days
		Spider mite	Floramite 240 SC @ 400ml in 1000l of water per ha	Bifenazate	7 days
		Foliar feed	Maxicrop Triple @ 4.0l in 1000l of water per ha	Seaweed extracts	0 days
08-Aug	**incl. Trials**	Mildew	Fortress @ 250ml in 1000l of water per ha	Quinoxyfen	14 days
		Botrytis	Rovral WG @ 1.0kg in 1000l of water per ha	Iprodione	2 days
		Foliar feed	Hortiphyte @ 4.0l in 1000l of water per ha	Phosphite	0 days
		Foliar feed	Maxicrop Triple @ 4.0l in 1000l of water per ha	Seaweed extracts	0 days
15-Aug	**incl. Trials**	Mildew	Systhane @ 450ml in 1000l of water per ha	Myclobutanil	3 days
		Mildew	Nimrod @ 1.4kg in 1000l of water per ha	Bupirimate	3 days
		Botrytis	Scala @ 2.0l in 1000l of water per ha	Pyrimethanil	3 days
		Foliar feed	Hortiphyte @ 4.0l in 1000l of water per ha	Phosphite	0 days

		Foliar feed	Maxicrop Triple @ 4.0l in 1000l of water per ha	Seaweed extracts	0 days
22-Aug	**incl trials**	Mildew and botrytis	Signum @ 1.5kg in 1000l of water per ha	Boscalid and pyraclostrobin	3 days
		Foliar feed	Hortiphyte @ 4.0l in 1000l of water per ha	Phosphite	0 days
		Foliar feed	Maxicrop Triple @ 4.0l in 1000l of water per ha	Seaweed extracts	0 days
29-Aug	Control	Mildew	Systhane @ 450ml in 1000l of water per ha	Myclobutanil	3 days
		Mildew	Nimrod @ 1.4l in 1000l of water per ha	Bupirimate	1 day
		Botrytis	Rovral WG @ 1.0kg in 1000l of water per ha	Iprodione	2 days
		Foliar feed	Hortiphyte @ 4.0l in 1000l of water per ha	Phosphite	0 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days
29-Aug	**Trials**	Mildew	Potassium bicarbonate @ 6kg in 1000l of water per ha	Potassium bicarbonate	0 days
		Mildew	Kumulus @ 1.5l in 1000l of water per ha	Sulphur	0 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days
31-Aug	Control	Earwigs	Hallmark zeon @ 125ml in 1000l of water per ha (EAMU 1705/11)	Lambda cyhalothrin	3 days
		wetter	Silwet L77 @ 1.5l in 1000l of water per ha	Silicon based wetter	0 days
02-Sep	Control	Mildew	Sulphur dust @ 7.5kgs/ha	Sulphur	0 days
05-Sep	Control	Mildew	Systhane @ 450ml in 1000l of water per ha	Myclobutanil	3 days
		Mildew	Nimrod @ 1.4l in 1000l of water per ha	Bupirimate	1 day
		Botrytis and mildew	Amistar @ 1.0l in 1000l of water per ha	Azoxystrobin	3 days
		Foliar feed	Hortiphyte @ 4.0l in 1000l of water per ha	Phosphite	0 days

		Foliar feed	Headland Complex @ 1.0l in 1000l of water per ha	Trace elements	0 days
05-Sep	**Trials**	Mildew	Potassium bicarbonate @ 6kg in 1000l of water per ha	Potassium bicarbonate	0 days
		Mildew	Kumulus @ 1.5l in 1000l of water per ha	Sulphur	0 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days
08-Sep	Control	Mildew	Sulphur dust @ 7.5kgs/ha	Sulphur	0 days
12-Sep	Control	Mildew	Systhane @ 450ml in 1000l of water per ha	Myclobutanil	3 days
		Mildew	Nimrod @ 1.4l in 1000l of water per ha	Bupirimate	1 day
		Foliar feed	Hortiphyte @ 4.0l in 1000l of water per ha	Phosphite	0 days
		Foliar feed	Headland Complex @ 1.0l in 1000l of water per ha	Trace elements	0 days
12-Sep	**Trials**	Mildew	Potassium bicarbonate @ 6kg in 1000l of water per ha	Potassium bicarbonate	0 days
		Mildew	Kumulus @ 1.5l in 1000l of water per ha	Sulphur	0 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days
15-Sep	**Trials**	Botrytis	Prestop @ 5kgs in 1000l of water per ha	Gliocladium	0 days
15-Sep	Control	Mildew	Sulphur dust @ 7.5kgs/ha	Sulphur	0 days
19-Sep	Control	Botrytis and mildew	Frupica SC @ 900ml in 1000l of water per ha	Mepanipyrim	3 days
		Botrytis and mildew	Amistar @ 1.0l in 1000l of water per ha	Azoxystrobin	3 days
		Foliar feed	Hortiphyte @ 4.0l in 1000l of water per ha	Phosphite	0 days
		Foliar feed	Headland Complex @ 1.0l in 1000l of water per ha	Trace elements	0 days
19-Sep	**Trials**	Mildew	Potassium bicarbonate @ 6kg in 1000l	Potassium	0 days

			of water per ha	bicarbonate	
		Mildew	Kumulus @ 1.5l in 1000l of water per ha	Sulphur	0 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days
22-Sep	Control	Mildew	Sulphur dust @ 7.5kgs/ha	Sulphur	0 days
26-Sep	Control	Mildew	Systhane @ 450ml in 1000l of water per ha	Myclobutanil	3 days
		Botrytis and mildew	Amistar @ 1.0l in 1000l of water per ha	Azoxystrobin	3 days
		Botrytis	Scala @ 2.0l in 1000l of water per ha	Pyrimethanil	3 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days
26-Sep	**Trials**	Mildew	Potassium bicarbonate @ 6kg in 1000l of water per ha	Potassium bicarbonate	0 days
		Mildew	Kumulus @ 1.5l in 1000l of water per ha	Sulphur	0 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days
02-Sep	Control	Botrytis and mildew	Serenade ASO @ 10.0l in 1000l of water per ha	*Bacillus subtilis*	0 days
		Botrytis and mildew	SB Plant Invigorator @ 4.0l in 1000l of water per ha	Carbonic acid diamide/Urea	0 days
		Foliar feed	Seniphos @ 3.0l in 1000l of water per ha	Calcium phosphate	0 days

Appendix 2. Temperature and humidity records

Tuesley Farm

Maximum and minimum temperatures were around 1°C lower through the early part of the season in the grower standard area compared to the IPDM. The mean 24 h humidity was higher throughout in the growing season the GS tunnel.

Table Appendix 2.1. Average monthly temperature comparison between IPDM and GS monitoring tunnels – Tuesley Farm 2012

	Max temp (°C)		Min temp (°C)		Average temp (°C)		Average Humidity (%rh)	
	IPDM	GS	IPDM	GS	IPDM	GS	IPDM	GS
Feb	30.0	29.0	-2.5	-3.5	8.8	8.7	87.9	90.1
Mar	36.0	35.0	3.0	4.0	13.6	14.0	84.3	87.0
Apr	33.0	34.0	2.5	3.0	12.6	12.5	79.5	86.1
May	34.5	34.5	2.0	1.5	15.6	15.3	77.1	78.8
Jun	28.0	28.0	7.5	7.5	16.6	16.6	81.1	81.5

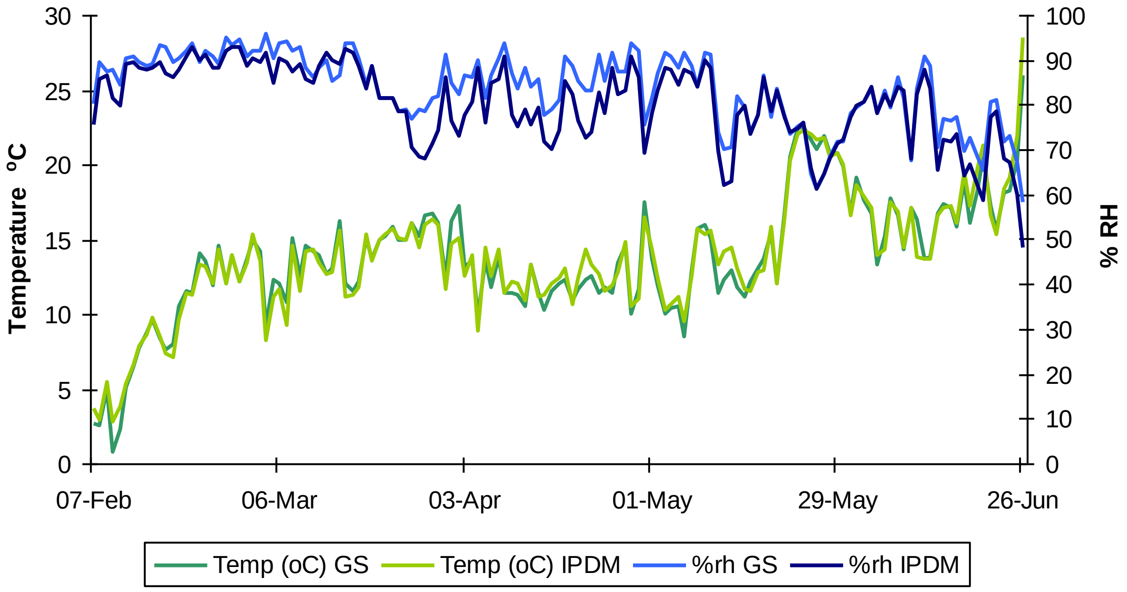

Figure Appendix 2.1. Mean 24 h temperature and humidity through growing season – Tuesley Farm 2012

SIX MONTHLY REPORT TO HORTICULTURE LINK PROGRAMME MANAGEMENT COMMITTEE

(60 month report due 31 Mar 2013)

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:	54-60 months
Number of Months Since Commencement:	60 months
Date of Last Management Meeting:	13 November 2012; 8 April 2013
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.	Y
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	Y

		commercial crops completed. Changes to the programme decided.	
P6.5	60	Blossom weevil super trap calibrated for pest monitoring purposes.	Y
P6.6	60	Efficacy of the super trap for control of strawberry blossom weevil by mass trapping quantified.	Y
P7.2.2	60	Second years experiments evaluating IPDM programme in commercial crops completed. Programme finalised and economic appraisal completed.	Y
P7.3	60	Best practice guidelines prepared. *Work in progress. Best practice guidelines are being prepared by the science partners and Scott Raffle HDC and will be published as a HDC factsheet which will be ready in summer 2013*	N

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.	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.	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.	Y
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.	Y
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.	Y

3.	**Milestones for the six month period:**	(from project proposal, or other more recently approved planning document)		
		See above		
4.	**Research report:**	(concise account including comments on whether targets are being met)		
See completion report				
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:**	**<u>Presentations in this 6 month period</u>** **4 Oct 2012 – Site visit to IPDM trial sites in Kent** **11 Oct 2012 – R. Saville gave an oral presentation 'Minimising pesticide residues in strawberries through integrated pest, disease and environmental crop management' at IOBC VIII international conference in Turkey.** **16 Oct 2012 – E. Wedgwood gave an oral presentation 'Utilising bees to vector biological fungicides for the control of strawberry grey mould (*Botrytis cinerea*).' AAB Advances in Biological control & IPM conference** **Nov 2012 – EMR poster giving an overview of the results of the project presented at Berry Gardens growers meeting** **21 Nov 2012 – J. Fitzgerald presented the IPDM programme findings and project results at HDC/EMRA soft fruit day** **20 March 2013 – J Cross presented the results of objective 4 at an international conference 'Future IPM Europe' at Riva del Garda, Italy** **Publications** **X.-M. Xu, J.D. Robinson and M.A. Else, 2013. Effects of nitrogen input and deficit irrigation within the commercial acceptable range on susceptibility of strawberry leaves to powdery mildew. European Journal of Plant Pathology, 135: 695-701.** **R. Saville, In press. Minimising pesticide residues in strawberries through integrated pest, disease and environmental crop management'. IOBC/WPRS Bulletin.**		
7.	**Exploitation plans:**	(give an update on perceived exploitation opportunities and future plans.)		
See completion report.				