Factsheet 13/13
Project SF 94 (Defra Horticulture LINK HL0191)

Soft Fruit

Reducing residues in strawberries through novel crop protection methods

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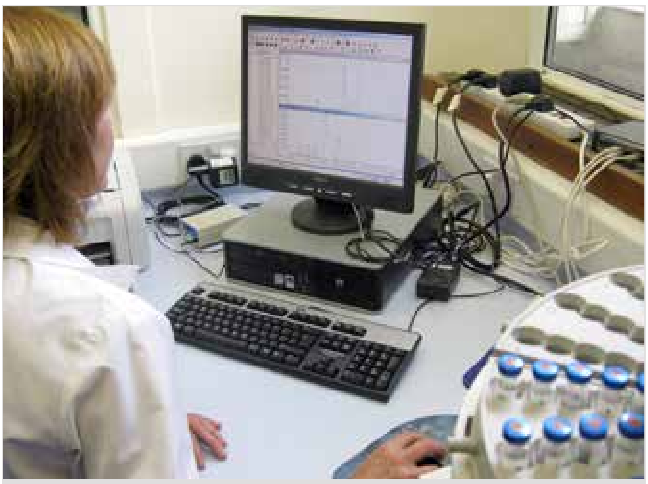
This factsheet summarises the recommendations made following the completion of a Defra funded Horticulture LINK project which aimed to develop novel crop protection methods that can be implemented in strawberry IPDM programmes.

Action points

- Biological control agents for powdery mildew control must be applied frequently to ensure adequate coverage of newly developing leaves and good spray cover on the undersides of leaves is crucial.
- A powdery mildew prediction model can be used which can help to reduce the number of sprays applied to maintain control of the disease.
- The BOTEM model can be used to forecast periods of Botrytis infection risk.
- Use of the BOTEM model suggests that fungicide applications are seldom necessary to manage Botrytis in early covered June-bearers.
- New guidelines are available to assist growers on deciding upon the need for management measures against blackspot.
- A bug vacuum, when mounted on the front of a tractor, can reduce numbers of tarnished plant bug to levels similar to those achieved using a spray of thiacloprid (Calypso), but frequent passes are required (twice/week) to keep feeding damage to a minimum.
- Good control of the complex of aphids that attack strawberry can be achieved through a combination of a post-harvest application of an aphicide (Calypso) and a programme of introductions of a mix of six parasitoids (parasitic wasps) in the spring/early summer.
- A new easy-to-use pheromone trap for strawberry blossom weevil is now commercially available for growers which can be deployed in crops at densities of up to 50 per hectare for precision monitoring. When monitoring populations with small numbers of traps, a catch of one blossom weevil per trap should be used as a threshold for scheduling conventional control treatments.

1. Strawberry growers are coming under increasing pressure to produce high quality berries whilst relying less upon conventional crop protection products



2. This Defra Horticulture LINK project has developed methods to reduce the incidence of residues in strawberries

Introduction

For some years, growers and their marketing groups have been seeking new methods to reduce detectable residues of traditional crop protection products in horticultural produce. For soft fruit growers, this has been a greater challenge due to the perishable nature of the product and resulting need to control fungal diseases close to harvest.

To find solutions to the challenge on raspberry, the HDC part funded a Defra Horticulture LINK project (HL0175, SF 74) to develop novel techniques to control the major pests and diseases that affect raspberries. This project successfully identified and developed a series of practices which are now being adopted by commercial growers to reduce reliance on traditional crop protection products.

In 2008, an industry consortium which included HDC, developed a new five year Defra Horticulture LINK project (HL0191, SF 94) entitled '*Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management*'. This focussed on strawberry, but had a similar remit to the previous raspberry project. The consortium (see Further information section) chose to work on powdery mildew, Botrytis, blackspot, European tarnished plant bug, aphids and strawberry blossom weevil, with the aim of incorporating these into an Integrated Pest and Disease Management (IPDM) programme.

The results of the work on each pest and disease are summarised in this Factsheet, along with the findings made when combined to form an integrated pest and disease management (IPDM) programme.

Powdery mildew

Powdery mildew (caused by *Podosphaera aphanis)* is one of the major fungal diseases of strawberry which can be particularly difficult to control in strawberries covered with protective tunnels. Infection on the leaf can cause up-cupping of the leaf surface, the appearance of white mycelium on both upper and lower surfaces of the leaf (Figure 3) and development of red blotching on the back of the leaf. White mycelium can also form on the developing fruits, rendering them unmarketable. The warm, humid environment that can prevail in tunnel crops on occasions is very conducive to infection and spread of mildew, so growers have traditionally relied upon the use of fungicides to protect the crop from infection.

3. Powdery mildew is often seen as white mycelium on both surfaces of the leaf

Previous HDC projects (SF 62 and SF 62a) studied the disease development in tunnel crops, which led to the publication of Factsheet 17/08 (*Control of strawberry powdery mildew under protection*). This provided a series of guidelines on how to manage strawberry crops under protection to reduce infection and how to protect the crop and control any infection which might occur. In addition, these projects developed a powdery mildew prediction model which allows growers to improve the timing of control measures.

In this Defra funded LINK project, a number of new investigations were made, whilst also further developing the prediction model into a form that is easier to use.

The scientists initially examined whether powdery mildew survives on planting material such as cold stored runners and tray plants. The work concluded that the probability of powdery mildew survival on cold-stored runners is very small, but it may survive cold conditions for several months on live green leaves.

It has long been suspected that increasing nitrogen application could increase powdery mildew infection but work in this project found that increasing nitrogen in table top strawberries had little effect on powdery mildew development on strawberry under protection.

A number of biocontrol agents and alternative products were screened for their ability to control powdery mildew. Overall, potassium bicarbonate (+ silicone wetter) had the greatest efficacy, although it still offered only 60% control. It was also found that biological control agents don't spread to newly developing leaves, so it is necessary to use frequent applications of these.

The powdery mildew prediction model was evaluated on both 60-day June-bearers and everbearers. Where used on early crops, it led to a significant reduction in the number of sprays applied to gain control (Figure 4). On later season crops, use of the model needs to be very carefully managed, with hygiene and tunnel environment management becoming even more important particularly if there is a high level of mildew inoculum. The software for the model is available from East Malling Research and HDC.

4. Use of the powdery mildew prediction model can lead to a reduction in the numbers of sprays applied to the crop

Botrytis

Botrytis cinerea is the cause of grey mould in strawberries (Figure 5). This is a ubiquitous pathogen which was traditionally the most common cause of fruit losses in strawberry crops. Warm, humid and wet conditions are conducive to infection, so the increased use of protective tunnels has significantly helped to reduce the incidence in strawberry crops, although rain splash at the edge of tunnels and high humidity can still give rise to infection.

5. Typical damage caused on strawberry by *Botrytis cinerea*

There was scope in this project to study the influence and effect of planting material on subsequent infection, to find new ways of eradicating the disease. In addition, the industry has been interested to find new ways of targeting control measures, as well as developing a previously constructed disease forecasting model, which had been developed by East Malling Research and HDC with Defra funding.

Initial work on incubated cold-stored strawberry runners showed that Botrytis is ubiquitous in various sources of planting material, being found inside crowns, on petiole stubs and on leaves.

Neither hot water treatment pre-planting nor fungicide application three weeks post-planting produced consistent differences in latent Botrytis.

In 2011 and 2012, work evaluated the efficacy of using pollinating bees as a vector for Prestop Mix (*Gliocladium catenulatum*) to control Botrytis in strawberry flowers under protection. The Prestop Mix powder was placed in trays inside bumble bee hives so that bees picked up the product when leaving to forage in the flowering crop. When compared to a crop receiving fungicide spray application, the incidence of latent fruit Botrytis was the same or less using the bee dispersed product in two consecutive seasons (2011 and 2012). It should be noted that for the purposes of this project, an extrapolated experimental approval was used for this method of application of Prestop Mix and at the time of publication of this Factsheet, work was ongoing to try to secure approval for this type of application in the UK. Prestop Mix is approved for use in protected strawberry crops as a spray.

Work also investigated the use of the Botrytis disease forecasting model BOTEM which uses weekly computer downloads from electronic temperature and humidity loggers placed in the crop canopy. When conditions were favourable for Botrytis, biofungicide sprays were applied (Serenade ASO in 2011, Prestop in 2012). In both years, such crops had no worse fruit Botrytis than those receiving a full chemical fungicide programme. Using the BOTEM model, it was also shown that there were seldom alerts in early-covered June-bearers and so fungicide application did not appear to be necessary to manage grey mould (Figure 6). The software for the BOTEM model is available from East Malling Research or HDC.

6. Using the BOTEM model, there were seldom any disease alerts in early-covered June-bearers

Blackspot

Strawberry blackspot (caused by *Colletotrichum acutatum*) first appeared in UK strawberry crops in the late 1980s. The most common symptoms appear as black sunken lesions, principally on ripe fruit (Figure 7), but black lesions may occasionally occur on petioles, stolons (Figure 8 - overleaf) and sometimes green fruit, which become covered with a characteristic salmon pink/ orange slime or spore mass when the weather is humid or wet.

In an effort to prevent its spread, it was initially designated a 'notifiable disease' by the UK government's plant health department. It has since become widespread, being favoured by warm, humid and wet conditions. Like Botrytis, its incidence has been reduced through the use of protective tunnels, but rainsplash at the edge of tunnels and the high humidity that can occur under protection, can still lead to significant infection.

7. Typical symptoms of blackspot on ripe fruit

8. Typical symptoms of blackspot on stolons

In this project, the objective was to establish the importance of alternative hosts as sources of inoculum of *C. acutatum* for strawberries in order to develop a sustainable IPDM system.

Early work used molecular methods to identify if genetic differences existed between isolates of *Colletotrichum acutatum* (the cause of blackspot) between different host plants. Overall, it was found that isolate differences were more related to site isolates rather than to host differences. However, further experimental work where isolates from other non-strawberry hosts were inoculated onto strawberry fruits and plants, signified that weeds and other non-strawberry hosts could act as a source of inoculum for *C. acutatum* in strawberry plantations.

Using this work and newly available information on black spot, simple guidelines have been developed to assist growers in deciding upon the need for management measures against blackspot. Information is also available on the relative efficacy of fungicides (currently approved for use on strawberries) at controlling blackspot. Information on non-chemical control measures is also provided. All of this information is summarised in Tables 1-4.

Table 1 Assessment of risk of blackspot infection or spread for a range of parameters

Parameter	Options	Disease risk
Site	Virgin site	Low
	Strawberry land with adjacent crops	High
	Strawberry in crop history, no adjacent crops	Moderate
Source of planting material	UK origin	Low
	Home produced non-certified	High
	Non UK origin	High
Cropping system	Open field	High - depending on weather
	Glasshouse	Low - depending on irrigation method
	Polytunnel early cover	Low-moderate
	Polytunnel pre-flowering cover	Moderate
Crop age	Annual or first year	Low
	2 years or older	Moderate-high
Cultivar type	June-bearer	Low-moderate
	Everbearer	Low-high
Irrigation	Overhead	High
	Trickle or drip	Low
Nutrition	High nitrogen inputs	High
Adjacent crops / weeds	Apples, cherries	Moderate-high
	Weed cover	Moderate-high
Herbicide use	glufosinate ammonium, glyphosate, diquat	Increased risk if weeds or runners infected

Table 2 Optimum environmental conditions for blackspot infection and spread

Parameter	Optimum
Temperature	20-25°C
Humidity	> 80%
Rainfall	Moderate rainfall

Table 3 **Efficacy of various fungicides approved for use on strawberry in the UK against strawberry blackspot**

Active ingredient	Typical product	Efficacy
azoxystrobin	Amistar	+++
Bacillus subtilis	Serenade ASO	?
bupirimate	Nimrod	0
captan	Alpha Captan	++
chlorothalonil	Various (eg Bravo 500)	+
cyprodonil + fludioxonil	Switch	+++
dimethomorph	Paraat	0
fenhexamid	Teldor	0
fenpropimorph	Corbel	++
fosetyl-aluminium	Aliette 80 WG	0
Gliocladium catenulatum	Prestop	?
iprodione	Rovral WG	0
kresoxim-methyl	Stroby	++
mepanipyrim	Frupica SC	+
myclobutanil	Systhane 20 EW	+
potassium bicarbonate	potassium bicarbonate plus wetter	?
pyraclostrobin + boscalid	Signum	+++
pyrimethanil	Scala	0
quinoxyfen	Fortress	
sulphur	Various (eg Headland Sulphur)	0
thiophanate-methyl	Cercobin WG	++ (sensitive isolates)
thiram	Thianosan WG	++

Key: +++ High ++ Medium + Low 0 Nil ? Unknown

Table 4 **Non-chemical control options and their importance for controlling blackspot**

Method	Importance
Certified disease-free plants	++++
Avoid overhead irrigation	++++
Sanitation	++++
Resistant cultivars	+
Strawing	+ (protected) +++ (outdoor)
Frequent harvesting	+++
Removing all ripe and damaged fruit at harvest	+++
Location	+
Rotation	+++
Soil-less culture	+

Key: ++++ High importance + Low importance

European tarnished plant bug

The European tarnished plant bug (*Lygus rugulipennis* – Figure 9) forages and feeds on developing strawberry flowers and if present in a crop even in low numbers (1 bug/40 plants), can give rise to fruit malformation, which renders it unmarketable. Where left uncontrolled, it can give rise to significant crop losses. Populations tend to peak in July and August, with the result that late season crops (most notably everbearers) tend to be worst affected.

9. Adult European tarnished plant bug

For this pest, the project consortium members were keen to exploit trap crops to attract it out of the adjacent strawberry crop and also to assess the use of hexyl butyrate, a substance produced by females to repel other females, as a repellent.

The scientists first assessed a range of weed species and cultivated plants to compare their relative attraction to tarnished plant bug when compared to strawberry. Of the weed species, mayweed and fat hen were the most attractive. The ornamental plant sweet alyssum (*Lobularia maritima* – Figure 10) showed greatest attraction so is a potential trap plant for the pest. Experiments showed that the cultivar 'Clear Cyrstal', a vigorous trailing variety, was best and it grew best in irrigated peat bags, either new or old. To avoid the risk of the sweet alyssum becoming a source of infestation, it needs to be sampled regularly to check levels of European tarnished plant bug and sprayed with insecticide (e.g. pyrethrum) when populations develop.

Further work evaluated the regular use of a tractor mounted bug vacuum to remove tarnished plant bug (Figure 11). Best results were achieved when the 'bug vac' was front mounted and it was shown to reduce numbers to half that of an untreated control and to comparable numbers in an area treated by a spray of Calypso. Frequent passes (twice per week) are needed to keep feeding damage to a minimum.

Other experiments evaluated the use of hexyl butyrate as a repellent of the pest. This was found to repel female tarnished plant bug, but the dispensers used need to be placed less than 1-2 m apart to be effective and their effects were more pronounced early in the season (May-June compared to September). It was therefore concluded that the cost of implementing such a strategy would not be economically viable for commercial strawberry producers.

10. Sweet alyssum is a potential trap plant for European tarnished plant bug

11. Front mounted bug vacuum can successfully reduce numbers of European tarnished plant bug in strawberries

Aphids

12. Potato aphid feeding on strawberry

A range of aphids can act as pests of strawberry. Most notable are the strawberry aphid (*Chaetosiphon fragaefolii*), shallot aphid (*Myzus ascalonicus*), potato aphid (*Macrosiphum euphorbiae* – Figure 12) and the melon and cotton aphid (*Aphis gossypii*). The shallot aphid feeds on the foliage of the strawberry plant in the winter and early spring, and gives rise to stunted and twisted foliage. Because of the severe damage this pest causes, infestations cannot be tolerated. Strawberry, potato and melon and cotton aphids feed and create sticky honeydew on the leaves and fruits, which can lead to contamination and unsaleable fruit. Aphids also act as virus vectors. The strawberry aphid can transmit strawberry mottle virus, strawberry crinkle virus, strawberry mild yellow edge virus and strawberry vein-banding virus. The melon and cotton aphid can also transmit strawberry mottle virus.

Four strategies were investigated in this project to find novel control measures for aphids. The use of flowering plants to attract natural enemies of aphids, the identification of semiochemicals to attract aphid predators and parasitoids and the use of biocontrol agents were all assessed. In addition, the use of late autumn (post-harvest) sprays using selective insecticides to reduce over-wintering populations was also examined.

Work to assess the effectiveness of flowering plants to attract aphid predators and parasitoids was largely unsuccessful and highlighted practical difficulties in this approach. Similarly, work to evaluate the effectiveness of plant derived semiochemicals to attract aphid predators and parasitoids into strawberry crops showed no scope for exploitation.

In other trials to assess the effect of selective insecticides to control aphids after harvest, the use of Calypso (thiacloprid) between late September and early November effectively reduced numbers of aphids (including strawberry and potato aphid) present on strawberry leaves the following spring.

Research to assess a mix of six parasitoids (Figure 13) which has been designed to contain the species that attack all the main aphid pests of strawberry, showed a significant reduction of strawberry aphid and potato aphid.

The latter two methods were therefore used in an IPDM programme later in the life of the project.

13. Release of six parasitoids to a strawberry crop

Strawberry blossom weevil

The strawberry blossom weevil (*Anthonomus rubi*) is a serious pest of strawberry which can give rise to significant reductions in fruit yields. Adults appear in strawberry crops in spring and summer. The adult female (Figure 14) lays her eggs singly in unopened flower buds, before feeding on the peduncle (flower stalk), which she then girdles with several small punctures. The flower buds cease to develop and consequently wither, with some actually dropping to the ground. Young crops with few flowers are particularly vulnerable to yield loss, though older plants often have an excess of flowers and some flower severing can be tolerated.

The strategy investigated by the scientists involved developing 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, including precision monitoring where larger numbers of traps are used to monitor populations locally so that sprays can be applied on a very local scale.

Work done prior to this project had identified and synthesised an effective lure using the male aggregation pheromone of strawberry blossom weevil.

14. Adult strawberry blossom weevil in a strawberry flower

Early work in this project developed and refined a green bucket trap with white cross vanes and a mesh grid over the trap funnel to prevent capture of larger non-target insects (Figure 15). It was also found that the green cross vanes which are optimum for catching tarnished plant bug, were almost as effective as for strawberry blossom weevil, as well as greatly reducing capture of non-target flying insects, making use of the grid unnecessary. This provides the opportunity of using a single trap for both pests.

Research also found that a volatile from the flowers of wild strawberry is a powerful synergist of the strawberry blossom weevil aggregation pheromone, increasing trap catches by three fold. Further work led to the conclusion that a trap threshold of one blossom weevil per trap could be used to ensure control measures are applied to keep damage to very low levels.

Investigations to assess the efficacy of the trap for precision monitoring showed that a trap density of 36 traps per hectare was sufficient for low populations but a higher density is required for increasing pest populations.

15. The strawberry blossom weevil lure is used in a green bucket trap with white cross vanes and a mesh grid over the trap funnel to prevent capture of non-target flying insects

IPDM programmes

In the final two years of the project, the practical discoveries made during the first three years were implemented alongside existing biocontrol techniques in IPDM programmes on five commercial farms in Surrey and Kent. On all sites, protected strawberry crops were used. The results were compared to the growers' existing standard practices.

Pest control

For aphids, the use of well-timed out of season aphicide sprays coupled with preventive introductions of Aphidsure fragaria (a six parasitoid mix) at three week intervals, starting 1-2 weeks after start of growth, provided good control compared to the grower practice. However, where a large population of melon/cotton aphid appeared, a single species parasitoid *Aphidius colemani* was more successful.

Traps for strawberry blossom weevil (36 traps/ha) did not reach a control threshold, so no control measure was required. This was in contrast to two of the grower control sites where conventional pest control programmes were followed.

For capsid and tarnished plant bug control, a combination of approaches was used including monitoring traps, alyssum trap plants and bug vaccing. The traps worked successfully and are now commercially available. However, the alyssum did not work successfully, whilst the bug vac requires further development before it can be used commercially.

Control techniques which are already well established in the industry were used for other pests. For two-spotted spider mite, western flower thrips and tarsonemid mite control, release programmes of *Phytoseiulus persimilis* and *Neoseiulus cucumeris* were used successfully (Figure 16). Although widely used already in the industry, their use in an IPDM programme (where insecticide applications were limited), enhanced their performance further. Pheromone delta traps were also used to monitor for tortrix species, whilst sticky glue was used around table top legs for earwig control which reduced the need to spray for the pest.

16. *Neoseiulus cucumeris* being applied by hand in a strawberry crop for western flower thrips and tarsonemid mite control

Disease control

The IPDM strategy focussed on non-chemical control of powdery mildew and Botrytis 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 inoculum for the period leading up to and during harvest.

The powdery mildew model was used to trigger spray applications of the fungicides potassium bicarbonate and sulphur. The system worked well for early season crops with a low mildew pressure, maintaining equivalent levels of mildew control with many fewer fungicide applications required.

For Botrytis, a combination of the bumble-bee dispersed (Figure 17) biocontrol agent Prestop Mix (*Gliocladium catenulatum*), along with the use of the BOTEM model to trigger spray applications of both Serenade ASO (*Bacillus subtilis*) and Prestop outside of the bee dispersal periods, were compared with a conventional fungicide programme. On three crops where this was trialled, equivalent and in some cases, lower levels of Botrytis were found on fruit compared with the conventional programme.

17. The biocontrol agent Prestop Mix was dispersed to strawberry flowers by placing trays of the powder formulation inside hives so that bumble bees picked up the product when leaving to forage in the flowering crop

Yields

Over the two years and five 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 appraisal of the IPDM system

In the final year of the project, the total cost of implementing the IPDM programme per hectare was compared to the total cost of running the grower programmes per hectare. This was achieved by comparing the cost of controlling each pest and disease. The comparison was made for soil grown June-bearer crops, coir grown table-top June-bearer 60-day crops and soil grown everbearer crops. The total costs for each are compared in Table 5 (overleaf).

Table 5 Comparison of costs incurred between grower control programmes and IPDM programmes for different production systems

Production system	Grower control cost/ha*	IPDM cost/ha*
Soil grown mainseason June-bearer	£2,707	£5,414
Coir grown 60-day June-bearer	£1,219	£973
Soil grown everbearer	£3,748	£6,324

***All costs are per hectare excluding VAT, and include plant protection products, staff time, trapping systems and other sundries.**

The individual cost comparisons for each disease and insect pest are included in the science section of the final report on Project SF 94, which is available from HDC (see Further information section).

Although the costs of running the IPDM programme tended to be higher, individually, certain strategies represented a saving. For instance, savings were made through a reduction in spray applications by using the powdery mildew and 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/ha), but reduced reliance upon fungicide sprays.

Trap monitoring was relatively cost effective as knowledge of low populations reduced spray applications (and hence potential residues) for European tarnished plant bug, common green capsid (Figure 18) 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. This would significantly reduce the cost per hectare by up to £1,600 compared to the use of aphid parasitod mix and would compare closely to the cost of aphicide use. Conventionally grown crops usually utilise biocontrol agents against two-spotted spider mites, western flower thrips and tarsonemid mite, however the earlier introduction of biocontrols at higher numbers in the IPDM programme gave better, although more costly control.

Overall the IPDM strategies tended to be more expensive, primarily as a result of some higher material costs and increased staff time spent managing traps and data loggers in addition to the task of replenishing fungal and arthropod biocontrol agents. However, equivalent yields and fruit quality can be obtained from the IPDM system.

In the short term, it is likely that strawberry growers will want to adopt some of the IPDM techniques developed in this project. Growers will need to tailor these to their site and cropping situation, selecting the most appropriate strategies according to particular pest pressures in that locality and population changes as the season progresses (Figure 19).

18. Pheromone trap used for monitoring common green capsid

19. Some growers use tractor mounted applicators to introduce bulk quantities of predatory insects

Further information

Project consortium details

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Berry World Ltd
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Suppliers of traps for blackberry leaf midge, common green capsid, European tarnished plant bug, raspberry cane midge, raspberry beetle and strawberry blossom weevil.

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Suppliers of traps for raspberry beetle

Other useful publications

HDC Factsheet 14/02. Strawberry blackspot

HDC Factsheet 18/04. Control of grey mould in strawberry crops

HDC Factsheet 19/04. European tarnished plant bug on strawberries and other soft fruit

HDC Factsheet 26/05. Aphids and their control on strawberry

HDC Factsheet 08/08. Strawberry blossom weevil

HDC Factsheet 17/08. Control of strawberry powdery mildew under protection

HDC Grower guide. Biocontrol in soft fruit

Project reports

Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management (SF 94, Defra Horticulture LINK HL0191)

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