Factsheet 26/05

Strawberry

Project No. SF 61

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Aphids and their control on strawberry

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Aphids are common and important pests of strawberry. They damage strawberry plants directly and two of the most common species, the strawberry aphid and the melon and cotton aphid, transmit virus diseases. New aphicides recently approved on strawberry (Calypso, Plenum, Chess) provide improved opportunities for chemical control and the current trend to growing strawberries under protection provides greater opportunity to control aphids biologically, by introductions of predators and parasites. This factsheet outlines the species that are economically important within strawberry production and outlines the various control options available.

Pest identification

Several species of aphid are commonly found on strawberry in the UK. Strawberry aphid, shallot aphid, potato aphid and the melon and cotton aphid are the most common, but many other species occur occasionally. Glasshouse and potato aphid is common under protection.

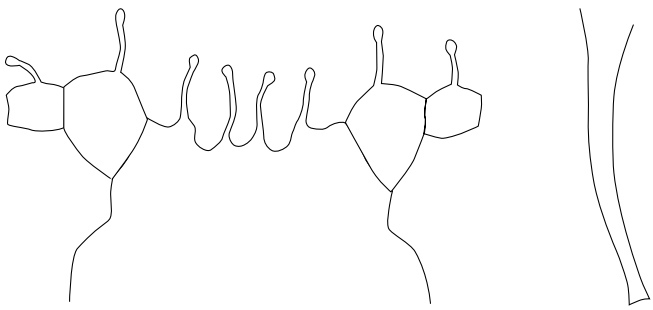
The different aphid species cause different types of damage and require different control approaches. For this reason, it is important to identify which species are present and their relative incidence. The different species are fairly easy to recognise by their appearance, distribution on the plant and the damage they cause. Close examination with a hand lens may sometimes be required for identification with certainty.

1 Strawberry aphid (close up above and colony below)

Strawberry aphid *(Chaetosiphon fragaefolii)*

Adults are small, whitish green with red eyes and their bodies are sparsely clothed with capitate body hairs (Figure 1, Diagram 1). Siphunculi (honey tubes) are moderately long. They are usually found on the undersides of leaves and, when infestations are heavy, on leaf petioles.

Diagram 1



Strawberry aphid showing forehead (right) and siphunculus (honeytube) (left). Note the presence of capitate hairs, which sparsely clothe the aphids body and are particularly easily visible on the forehead. These capitate hairs are only found on strawberry aphid.

Melon and cotton aphid *(Aphis gossypii)*

Aphids are very variable in colour, from bright yellow, to dark green to black, with younger individuals in a family group characteristically being lighter and more mature individuals darker (Figure 2). The legs are lighter, but not uniformly white (see black bean aphid *(Aphis fabae)* below), and in common with other *Aphis* species, melon and cotton aphids have a domed head between the antennae. The aphid forms dense colonies that secrete honeydew copiously. This species is often resistant and survives treatment with many aphicides.

2 Melon and cotton aphid *(Aphis gossypii)* adult, left; aphids in strawberry flower, right

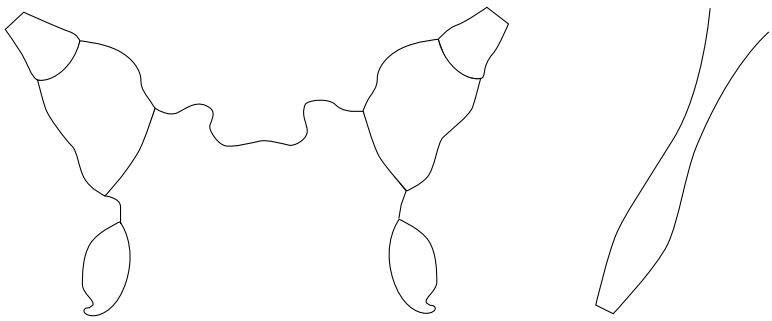
Shallot aphid *(Myzus ascalonicus)*

Adults are small, pale brown or yellowish or greenish brown (Figure 3). The front of the head is emarginate (convex) between the antennae and prominences are slightly convergent (Diagram 2). Siphunculi (honey tubes) are distinctly swollen towards the tip (Diagram 2). This aphid is mainly found in the growing points of plants, often in small numbers and can be difficult to find. However, unlike the other aphids that feed on strawberry, shallot aphid causes noticeable stunting of the growth and characteristic twisting of leaves (Figure 4).

3 Shallot aphid

4 Shallot aphid damage to strawberry

Diagram 2



Shallot aphid showing siphunculus (honeytube) which is distinctly swollen towards the tip and the prominences on the forehead below the base of the antennae.

Potato aphid *(Macrosiphum euphorbiae)*

Adults are large, with individuals in a colony ranging from yellowish-green to pink. Siphunculi (honeytubes), are very long, cylindrical and sometimes dark tipped (Figure 5).

Glasshouse and potato aphid *(Aulacorthum solani)*

Adults are yellowish green with long, thin, slightly tapered, dark tipped and flanged siphunculi. The nymphs are shiny green, with a rather bright green or yellow patch at the base of each siphunculus (Figure 6).

Other aphid species

Several other species of aphid can occasionally be found on strawberry. *Acrythosiphon malvae rogersii*, a medium sized green aphid with long, flanged siphunculi (honey tubes) often occurs in mixed colonies with the potato aphid. The violet aphid, *Myzus ornatus*, is occasionally found on strawberry, more frequently on protected crops. This species has a very wide host range and is of only minor importance on strawberry. Adults are small, pale brownish or dull green with a distinctive dark pattern on the body. The siphunculi (honeytubes) are pale, moderately long and cylindrical. The head has distinctly convergent prominences, similar to those of the shallot aphid. The black bean aphid, *Aphis fabae*, is sometimes found in small colonies. This aphid has a coal black body (nymphs and adults), a domed head between the antennae (a characteristic of *Aphis* species) and distinctive white legs. The strawberry root aphid, *Aphis forbesi*, is a small blue-green aphid which feeds upon both strawberry foliage and roots and the yellow rose aphid (Figure 7), *Rhodobium porosum*, are common pests of strawberry in continental Europe.

5 Potato aphid on strawberry leaf

6 Glasshouse and potato aphid

7 Yellow rose aphid

Photo courtesy of J.L. Castner & University of Florida

Aphid transmitted virus diseases

Several aphid-borne viruses infect strawberry, but the major ones in Europe are strawberry crinkle virus, strawberry mottle virus, strawberry vein banding virus and strawberry mild yellow edge virus. Most strawberry varieties grown today do not show obvious symptoms when infected with one of these aphid borne viruses. However, the viruses often occur in complexes and cause distortion of the plant parts, which may render fruit unmarketable.

Since no practical treatments to cure virus-infected plants are available to the grower, virus diseases of strawberry are predominantly controlled though the use of virus-free planting material together with control programmes for their transmitting agents, particularly aphids.

Strawberry and melon and cotton aphids transmit virus diseases. These different virus diseases have different persistencies within their aphid vectors and different acquisition and transmission times and latency periods within the aphid (Table 1). These factors affect the rate of spread of the virus and the likely success in limiting virus infection by controlling the aphid vectors. Semi-persistent viruses are rapidly acquired by their aphid vectors and rapidly spread to new plants. Aphicides have to control the aphids rapidly and ideally have a strong repellent and/or anti-feedant effect. Once a strawberry plant is infested with virus, it remains so for the rest of its life, acting as a source of infection.

Strawberry crinkle virus

Crinkle virus is common in UK strawberry crops, though many growers have difficulty recognising the symptoms. All varieties can be infected, but infected plants may be symptomless. In sensitive varieties, leaves may have chlorotic spots and leaflets be uneven in size. Distorted, or crinkled, petioles and leaves may be reduced in size (Figure 8a-b).

The virus is transmitted in a replicative, persistent manner by strawberry aphid. The aphid acquires the virus by feeding on an infected host. The virus replicates inside the aphid but has a latent period of 10–19 days under optimal conditions; at lower temperatures the latent period is longer. Aphids retain strawberry crinkle virus as long as they live after acquisition of the virus. A single aphid can spread the virus to many plants.

Strawberry mottle virus

Strawberry mottle virus is the most common virus of strawberries and is present wherever they are grown. The virus has numerous strains, which are often symptomless in strawberry varieties. Severe strains may cause a decline in vigour and reduce yield by up to 30%. Strawberry mottle virus is vectored in a semi-persistent manner by the strawberry and the melon and cotton aphids. The virus can be transmitted in a feeding period of a few minutes.

Photo courtesy of Gerard Jongedijk, Naktuinbouw Test Centre, Horst, NL

8a Strawberry crinkle virus

Photo courtesy of Gerard Jongedijk, Naktuinbouw Test Centre, Horst, NL

8b Strawberry mottle virus

Photo courtesy of Gerard Jongedijk, Naktuinbouw Test Centre, Horst, NL

8c Strawberry vein banding virus

Photo courtesy of Gerard Jongedijk, Naktuinbouw Test Centre, Horst, NL

8d Strawberry mild yellow edge disease

Strawberry vein banding virus

Strawberry vein banding virus is the least common of the four major aphid-borne virus diseases of strawberry. Three types of symptoms are known to be caused in sensitive indicator plants by different strains of strawberry vein banding virus: vein banding, leaf curl and chlorosis. However, most currently grown cultivars are symptomless. Mixed infections with crinkle virus can cause serious losses in yield, fruit quality and runner production. Interactions with strawberry mottle or mild yellow edge virus result in mild disease. Strawberry aphid transmits the virus in a semi-persistent manner. An inoculation access period of about 30 minutes is required for transmission. Aphicides used to control the aphid vectors and so prevent transmission of this virus have to be fast acting or have a good anti-feedant or repellent effect.

Strawberry mild yellow edge disease

Strawberry mild yellow edge is one of the most widespread virus diseases of strawberry. In the field, the combination of strawberry mild yellow edge with strawberry mottle or strawberry crinkle virus causes the disease previously known as yellows. The variety Cambridge Favourite is particularly susceptible though most modern varieties are tolerant and do not show symptoms. The virus is vectored by the strawberry aphid and related species in a persistent, circulative manner in the field. Acquisition and inoculation access periods lasting overnight or up to several days are required for efficient transmission. Once the virus has been acquired, the aphid remains infected with the virus for most if not all of its life. The virus complex can thus be spread over considerable distances by aphid vectors transported by air currents. Since strawberry mild yellow edge requires longer inoculation access feeding than the semi-persistent viruses, systemic insecticides have proven useful in its control.

Table 1 Relative persistencies of aphid transmitted strawberry viruses and their acquisition, transmission and latency times

Aphid virus vector	Virus	Persistence in aphid	Acquisition by aphid and transmission to crop times	Latency period in aphid
Strawberry aphid *(Chaetosiphon fragaefolii)*	Crinkle	Persistent	<24 hours	10–19 days
	Mottle	Semi-persistent	Minutes/a few hours	None
	Mild yellow edge	Persistent	Hours/days	Days
	Vein banding	Semi-persistent	Minutes	None
Melon and cotton aphid *(Aphis gossypii)*	Mottle	Semi- or non-persistent	Minutes/a few hours	None

Crop damage

The different aphid species cause different types of crop damage. All the species debilitate the plant by sucking sap and excreting honeydew that contaminates the foliage, flowers and fruits. Sooty moulds grow on the honeydew causing blackening. Fruits and/or the calyx may be contaminated by aphids themselves, their dead bodies or their cast skins. The different species infest the plants in different ways and cause very different symptoms of plant distortion.

Strawberry aphid

Strawberry aphids do not distort the foliage of infested plants but they do make them sticky with honeydew. This species is most important as a potential vector of crinkle and yellow edge virus diseases.

Shallot aphid

Shallot aphids feed during winter and early spring, mainly in the growing points and young leaves, causing strong plant distortion symptoms. Infested plants become severely stunted when growth commences in spring, the petioles being shortened and the leavers curled and twisted (Figure 3). Blossom trusses on infested plants are similarly affected, cropping is much reduced and fruits are small and of poor quality. The symptoms tend to appear first on individual plants or in small patches, but damage soon spreads until large areas are affected. Some growers mistake the damage for that caused by tarsonemid mite (See HDC factsheet 15/03).

Potato aphid

Potato aphid causes little direct damage to strawberry. Very heavy infestations weaken the young shoots and cause some honeydew contamination.

Melon and cotton aphid

Melon and cotton aphids infest foliage and flowers forming dense colonies in patches which produce copious secretions of honeydew which rapidly become blackened by sooty mould. This aphid can also transmit mottle virus (see above).

Life cycles

Strawberry aphid

Wingless strawberry aphids breed on strawberry throughout the year, except during extremely cold winter weather. Populations reach their height in summer. Winged aphids, which spread infestations to new plantations, occur in May and June with smaller, less important generations from October to December. There is no sexual stage in the life cycle and eggs are not laid.

Shallot aphid

Winged shallot aphids migrate to strawberry in the autumn where colonies of wingless aphids develop throughout the winter and spring. In May or early June, winged forms develop which fly to various summer hosts. Colonies on strawberries decline and eventually die out.

Potato aphid

Potato aphid can breed on strawberries all year round under suitable conditions but populations are greatest on the young foliage in April and May when winged forms develop which migrate to various summer hosts including potato. Small numbers of wingless forms may remain on strawberry throughout the summer.

Melon and cotton aphid

Melon and cotton aphid has a very wide host range. It does not have a sexual stage in the UK and no eggs are laid. In warm conditions, the aphid breeds continuously, winged forms that migrate to start new infestations being produced at any time in response to crowding. The aphid breeds rapidly at moderate to high temperatures but is not cold-hardy and cannot survive prolonged periods of sub-zero temperatures. It does not normally survive the winter outdoors in the UK. Infestations in spring and early summer usually originate from a wide range of glasshouse or protected crops.

Control

Natural enemies

Predators

Aphids are preyed on by a wide range of generalist predatory arthropods including; ladybirds, spiders, rove beetles, lacewing and hoverfly (syrphid) larvae, predatory flower bugs *(Anthocoris* and *Orius* sp.*)* and other predatory bugs and anystid mites.

Several studies have shown that spiders are often the most abundant group of predators. Over 20 species may be present. The predatory flower bug *Anthocoris nemorum* is one of the commonest predatory bugs that feed on aphids on strawberry but the smaller species *Orius niger*, *Orius majusculus* and *Orius laevigatus* also occur naturally in summer as well as nabid bugs and predatory mirids. Ladybird and lacewing larvae may also occur in small to moderate numbers. Other common predators include the rove beetles, *Tachyporus hypnorum* and *Tachyporus obtusus*, and the predatory mite *Anystis agilis*. Many species of ground beetle (carabids) that occur in strawberry fields (some feed on strawberry fruits) are known to be predators of aphids in cereal fields. However, their role as predators of aphids in strawberry crops is largely unknown. One of the factors likely to influence their importance is the extent to which they will climb onto plants to seek prey. Experiments at EMR showed that some species can climb onto strawberry leaves.

The relatively short life of modern strawberry plantings counts against the establishment of large natural enemy populations. Also, the practice of fumigating the ground before planting strawberries is likely to deplete populations of ground-dwelling predators. Many insecticides used on strawberry are toxic to predators and large natural populations cannot develop where such sprays are used (see below).

Aphid numbers often reach damaging levels despite the presence of large numbers of predators. The increase in predator numbers often lags behind the rapid development of aphid populations when weather and plant growth conditions are favourable in spring and summer. Because aphids, in particular strawberry aphid, are virus vectors, the numbers of aphids that can be tolerated are rather low. The natural enemy complex cannot regulate them consistently to such low levels. Supplementary introductions of predatory insects such as predatory midges *(*eg *Aphidoletes aphidimyza)* or lacewing larvae sp. can be made for biocontrol of aphids in protected strawberry crops (see below).

Parasitic wasps

Mummies of aphids parsitised by parasitic wasps (parasitoids) such as *Aphelinus* and *Aphidius* sp. are often numerous in strawberry crops with large aphid populations, particularly in summer. Hyperparasites, which parasitize the parasitoids, may reduce their effectiveness. Though natural parasitoid populations and parasitism rates may be high, aphid numbers may still reach damaging levels. Supplementary introductions of parasitic wasps can be made for biocontrol of aphids in protected strawberry crops (see below).

Fungi and microbial agents

Outbreaks of the fungal insect pathogen *Entomophthora planchoniana* occur naturally in strawberry aphid populations, usually in prolonged periods of moderately warm, very humid conditions. Outbreaks are irregular in time and intensity and only occasionally play a significant part in regulating aphid populations. This natural pathogen cannot be easily cultured in artificial media and therefore cannot currently be used as a biocontrol agent, though other pathogenic species may offer opportunity (see below).

Enhancing natural enemies

- Persistent, broad-spectrum insecticides, particularly synthetic pyrethroids, are harmful to a wide range of natural enemies and their use should be avoided if possible. The best way of increasing natural enemies is to avoid the use of such insecticides and use only selective

insecticides or cultural, biological and biotechnological control approaches.

- Populations of natural enemies are increased by providing stable habitats with a diverse range of plants around the plantation. In reality, there is little practical opportunity of increasing plant diversity in plantations themselves. However, the size of plantations may be limited and wildlife areas provided. It should also be noted that some pests (eg strawberry blossom weevil) use such areas as overwintering sites.

- Successive sowing of flowering herbs in and around the plantation will provide an alternative food source for some natural enemies, notably hoverfly adults, the larvae of which are predators of aphids. Care in choice of species is important, as many flowering plants are hosts to the European tarnished plant bug, a damaging pest of strawberries at low population densities (see HDC factsheet 19/04).

Crop monitoring

As aphids are such common and important pests of strawberry, it is imperative that growers familiarise themselves with the different species, the damage symptoms they cause and how and where to look for them. Crops must be examined carefully and regularly for infestation and damage, including virus infection, as part of the routine crop-monitoring programme.

- It is recommended that each strawberry field is examined at least fortnightly, and preferably weekly, for pests and diseases during the growing season.

- At the start of each inspection the whole area should be examined from a high spot in or next to the field for patches of stunting or abnormal growth or colouring.

- If patches are detected, they should be closely inspected and the cause or causes diagnosed. The cause could be aphids, but there are a wide range of other possible causes including red core, crown rot, tarsonemid mite, verticillium wilt, vine weevil, waterlogging, etc.

- The crop inspection should be continued making a zig-zag transect across the field stopping at a minimum of 10 points per ha.

- At each point, all the plants in a 5 m radius should be overviewed for stunting, distortion, poor growth, honeydew and/or sooty mould contamination of foliage or fruits. If present, the particular plant(s) should be closely inspected and the cause diagnosed.

- One plant should be selected at random from each of the 10 points and closely examined for the signs of pest or disease infestation or damage. Presence or absence of infestation or damage should be recorded.

- For aphids, it is important to examine the undersides of the youngest emerging leaves and the undersides of older leaves. Shallot aphid may occur singly or in small numbers between the folds of very young, unfurling leaves, which are usually characteristically distorted. Melon and cotton aphid may occur in the flowers. Leaves, flowers and fruits, including stalks, should be examined for other tell tale signs of aphid infestation such as a glistening or stickiness of honeydew or the presence of cast skins. Blackening by sooty mould usually indicates the infestation has been present for some time or at least some time ago.

Unfortunately, economic damage thresholds for the different aphids pests of strawberry have not been determined. Simple thresholds that do not take into account time of season, growth stage, crop age, growing conditions and crop value are likely to be misleading. In general, only very low populations (< 5% plants infested) of damaging aphid species such as strawberry aphid or melon and cotton aphid can be tolerated early in the season. When low levels of these species are found, more frequent (twice weekly) and careful monitoring should be applied. There is a zero tolerance for shallot aphid. Potato aphid is less damaging and consequently higher thresholds apply.

Biocontrol

Several predators and parasitoids available from biological suppliers can be used as biocontrol agents of aphids on strawberry. The most useful currently are the predatory midge *Aphidoletes aphidimyza*, the parasitic wasps *Aphidius colemani* and *Aphidius ervi* and larvae of the green lacewing, *Chrysoperla carnea*. A number of other biocontrol agents are also available such as the ladybird *Adalia bipunctata*, predatory bugs such *Orius* and *Anthocoris* species and the entomopathogenic fungus *Lecanicillium longisporum* (formerly named *Verticillium lecanii*), but these are either at best only partially effective, or expensive or have other snags or difficulties.

- Biocontrol approaches for aphids on strawberry are only likely to be effective and reliable in protected crops.

- Biocontrol is unsuitable for aphids in crops for propagation, at least as a stand alone method, because low populations of aphids can transmit significant levels of virus. There is only a very low tolerance of aphids in the Plant Health Propagation Scheme, nil on high health stocks

- Because of the large number of aphid species that can occur on strawberry under protection, biocontrol agents with a broad host range that can control several aphid species are preferable to biocontrol agents that are aphid species specific.

Predatory midge *Aphidoletes aphidimyza*

The predatory midge *Aphidoletes aphidimyza* is currently the most useful and effective biocontrol agent for aphids on strawberry (Figure 9). It has a wide host range and can control all the aphid species that occur on strawberry. Adult midges (Figure 10) are mainly active at night. Females search for aphid colonies in which to lay their eggs. The number of eggs laid depends on the density of the infestation. The midge larva that hatches is bright orange and immediately attacks the aphids. The larvae inject a poison into an aphid to paralyse it and liquify it internally, making it easier for the larva to consume. When many aphids are available, the midge larvae kill more aphids than they can consume, making the midge a more effective and reliable predator. In experiments at EMR (HDC project SF 61) midge larvae consumed a mean of 45 young strawberry aphids during their development.

Temperature has a marked effect on the activity of *Aphidoletes aphidimyza*; in particular, a minimum dusk and night temperature of approx. 14°C is required. This limits the use of *Aphidoletes* until about mid-May at the earliest in tunnels, though may be used prior to this in heated glasshouses. *Aphidoletes aphidimyza* also needs 15.5 hours of daylight per day to prevent it going into diapause (a state of hibernation) and is only likely to be fully effective between March and October, unless there is adequate supplementary lighting. The diapause switching mechanism acts in the semi-mature larvae. It is therefore possible to use the midge adults with shorter day lengths earlier in the season, though the midge will not complete its development.

It is recommended that a series of introductions (Tables 2) should be made until the midge is well established with predatory midge larvae present in aphid colonies and the aphids are effectively being controlled.

Aphidoletes aphidimyza pupates in the soil and the midge may be less successful at completing its life cycle where the soil or growing medium is covered with polythene. This may prevent the midge from establishing and prolong the need for introductions.

Aphidoletes aphidimyza is supplied as late pupae, often loose in vermiculite in tubes or pots. The midge typically costs approximately £12/1000 at the time of writing *(2005). The midge needs high humidity conditions for adult emergence and successful host finding and reproduction. For products from some suppliers, the right conditions are claimed to be provided by the delivery bottle, it being only necessary to remove the cap and place the container within the crop. For others, it is recommended that special emergence pots are used to provide the emerging midges with the right conditions. Typically, 15 emergence pots are needed per hectare.

The adult midge is very sensitive to insecticides, the midge larvae moderately so. Use of harmful insecticides should be avoided if possible, especially persistent ones (see Table 4 & 5). Sulphur sprays are harmful and continuous use of sulphur burners can disrupt host finding by the adult female and should be avoided, particularly at dusk when host finding occurs.

Although *Aphidoletes aphidimyza* offers the most promise for biocontrol of the range of aphid species in strawberries, its' reliability and effectiveness, and safe methods of integrating its use with insecticide and fungicide sprays, are largely unproven in tunnels. In field experiments, where four introductions of adult midges were made to control strawberry aphid, very few midge larvae were found in subsequent leaf samples and there was no effect on aphid numbers (HDC project SF 61). Different release techniques need to be investigated.

Table 2 The recommended rate of *Aphidoletes aphidimyza* introduction depends on the density of aphid infestation as follows:

	Average rate of predator introduction
Preventive treatment	0.25/m^2/week
Curative treatment of low populations	0.5–1.0/m^2/week
Curative treatment of higher populations	1–2/m^2/week
Treatment of aphid hot spots	5–10/m^2 as a one off introduction

Table 3 Recommended rates of *Aphidius ervi* or *Aphidus colemani* introduction are:

	Average rate of parasitic wasp introduction
Preventive treatment	0.25/m^2/week
Curative treatment of low populations	0.5–1.0/m^2/week

Photo courtesy of Bob Knight, Koppert

9 *Aphidoletes aphidimyza* larva predating aphids

Photo courtesy of Bob Knight, Koppert

10 *Aphidoletes aphidimyza* adult

Parasitic wasps *Aphidius colemani* and *Aphidius ervi*

These parasitic wasps lay their eggs inside the aphids body (Figure 11) which turns into a mummy (Figure 12). They are effective but more host specific as follows:

- *Aphidius ervi* attacks potato aphid and glasshouse potato aphid
- *Aphidius colemani* is effective against melon and cotton aphid
- No species that is effective against strawberry aphid that is commercially available. A naturally occurring parasitoid, *Aphidius eglanteriae*, is often found in strawberry plantations, (HDC project SF 61) but numbers generally lag behind the population growth of the aphid.

The parasitoids are supplied in aphid mummies, costing about £19 per 250 (2005) for *Aphidius ervi* and less than half that for *Aphidius colemani*. See Table 3 for introduction rates

Parasitic wasp *Aphelinus abdominalis*

This small parasitic wasp can also be used for biocontrol of aphids on strawberry. However, it is slower acting and requires higher temperatures than the other biocontrol species given above. Its effectiveness against the full range of aphid species that attack strawberry is uncertain. This species will not parasitise the strawberry aphid (HDC project SF 61).

Predators

Lacewing larvae (Figure 13), such as the green lacewing *Chrysoperla carnea*, have some promise for aphid control in strawberry though their effectiveness and reliability are inadequately proven. Defra funded experiments at EMR showed that a larva consumes up to 800 strawberry aphids during its development. However, releases of 8 larvae per plant were needed to significantly reduce strawberry aphid numbers in field grown plants. They are more tolerant to low temperatures, and some chemicals (eg fungicides) than *Aphidoletes aphidimyza* and the parasitic wasps *Aphidius colemani* and *A. ervi*. Rates of about 10/m^2 are normally used for curative treatment; however a preventative programme at approx. 1/m^2 may have some value, such as in organic crops, but would be relatively expensive (approximately £200/ha/introduction). Introductions would need to be continued until the predators are well established and the aphids under control.

Various other predators including ladybirds and predatory bugs such as *Orius* and *Anthocoris* are also available from biological suppliers and will predate aphids in strawberry crops. However, they are costly and their effectiveness and reliability are unproven. They may be useful in aphid hot spots where rapid control is required. In cage experiments to determine the effectiveness of *Orius laevigatus* in reducing strawberry aphid numbers on potted plants (HDC project SF 61), a single release of 3 and 15 adults (males plus females) per six plants significantly reduced strawberry aphid numbers four weeks after release. This needs to be validated in field experiments on tunnel grown strawberries. Multiple releases should give quicker control.

11 *Aphidius ervi* about to parasitise aphid

Photo courtesy of Bob Knight, Koppert

12 *Aphidius colemani* mummy (right)

13 Lacewig larvae consuming aphid

Chemical control

Several insecticides approved for use on strawberry crops are effective against aphids (Tables 4 & 5) and several have a specific label recommendation for control of these pests. Some have harmful effects on biocontrol agents commonly used in strawberry crops.

Bifenthrin **(Talstar):**
This synthetic pyrethroid insecticide is recommended for control of two-spotted spider mite on strawberry and other crops. It is also approved for control of aphids on many crops including brassicas and cereals. Though it is not specifically recommended for aphid control on strawberries, it is likely to be fairly effective against aphids with which it comes into contact. It will not control resistant strains of the melon and cotton aphid. It acts by contact and residual action only and is not systemic or translaminar. It is therefore unlikely to be fully effective against aphid colonies that are inaccessible to sprays. Control of shallot aphid is unlikely to be successful with this insecticide. The main drawback of bifenthrin is that it is a broad-spectrum insecticide with persistent harmful effects against many biocontrol agents and natural enemies including the predatory mites *Phytoseiulus persimilis* and *Amblyseius cucumeris*, and all the biocontrol agents for aphids described above.

Chlorpyrifos **(Lorsban, Equity etc):**
This moderately persistent organophosphorus insecticide is fairly effective against aphids. It is often used on strawberries before flowering for control of several pests including blossom weevil, caterpillars and aphids. It will not control resistant strains of the melon and cotton aphid. It has moderately long (6–8 weeks) harmful effects on the predatory mite *Amblyseius cucumeris* which is frequently used for biocontrol of tarsonemid mite and thrips in strawberry crops. It is also harmful to natural enemies and all the biocontrol agents for aphids described above.

Nicotine **(XL-All Nicotine etc):**
Nicotine is approved for control of aphids on soft fruit and many other crops including strawberries. It is moderately effective, though seldom used because of its short persistence, toxicity to humans (including through skin contact) and the need to wear a respirator when applying sprays. Its main use on strawberries is for control of resistant strains of the melon and cotton aphid, which are difficult to control with most other aphicides. It has short-term harmful effects to predatory mites.

Thiacloprid **(Calypso):**
This systemic nicotinyl insecticide is approved for control of rosy apple aphid on apple and has Specific Off-label Approvals (SOLAs) for use on several other crops including outdoor strawberries (Notice of Approval number 2727/2003) and protected strawberries (Notice of Approval number 1497/2004). It will control resistant strains of the cotton-melon aphid. Calypso is moderately harmful to the predatory mites used as biocontrol agents and very harmful to *Orius* predatory bugs.

Pirimicarb **(Aphox):**
This partially systemic carbamate aphicide is approved for control of aphids on strawberry and many other crops. It works best in warmer conditions. It is effective for most of the aphid species that occur on strawberry though it will not control resistant strains of the melon and cotton aphid. It is a selective insecticide and is safe to most natural enemies and biocontrol agents though it is reported to have limited, short term harmful effects on *Amblyseius cucumeris* (Tables 4 & 5). It has a 3-day harvest interval on strawberries. Note that pirimicarb is an anticholinesterase compound.

Pymetrozine
(Chess WG, Plenum WG):
This systemic insecticide is approved for control of aphids on ornamentals, protected cucumbers and potatoes and now has a Specific Off-label Approvals (SOLA's), 1072/2003 (Chess WG) and 1073/2003 (Plenum WG), for use in strawberry, cane fruit and currants. However, the 12 week harvest interval will often preclude its use in fruiting strawberry crops, a severe limitation. It acts mainly as an aphid anti-feedant. Feeding normally stops within minutes of application. Then aphids starve to death. This may take a few hours in summer but may take several days in cold winter conditions. Note that on strawberry, Chess is only approved for use in protected crops and Plenum WG is only approved for use in outdoor crops. Pymetrozine is likely to be effective against aphids on strawberry The main advantage of this product is that is comparatively safe to natural enemies and biocontrol agents, including the predatory midge *Aphidoletes aphidimyza*. It is also safe to bumble bees.

Table 4 Insecticides approved for use on strawberry that are recommended or likely to be effective, at least partially, for control of aphids

Choice of insecticides - Efficacy factors										
Active ingredient	**Trade name (examples)**	**Class**	**Persistence**	**Approval (label recommendation)**		**Safety to biocontrol agents**				
				Pest	**Likely efficacy**	***Phytoseiulus***	***Amblyseius cucumeris***	***Amblyseius californicus***	***Aphidoletes aphidimyza***	***Aphidius ervi/colemani***
bifenthrin	Talstar	pyrethroid	long	Two-spotted spider mite in strawberries and other crops. Aphids in brassicas, cereals and hops.	Moderate	h, 8–12 wks	h, 8–12 wks	s	h, 8–12 wks	h, 8–12 wks
chlorpyrifos	Lorsban, Equity etc	OP	long	Aphids, caterpillars, spider mites, blossom weevil, vine weevil in strawberries.	Good except against resistant melon-cotton aphid	mh, 0.5 wks	h, 6–8 wks	mh, 2 wks	h, ? wks	h, ? wks
nicotine	XL All 95% nicotine	alkaloid	short	Aphids, capsids, leafhoppers, sawflies in soft fruit and other crops	Good and should control resistant melon and cotton aphid	h, 1 wk	h, 1 wk	?	h, 0 wks	?
pirimicarb	Aphox	carbamate	short	Aphids in strawberries and many other crops	Good except against resistant melon and cotton aphid	s	mh, 3 wks	s	s, larvae h, adults 1 wk	s
pymetrozine	Chess WG* Plenum WG*	azomethine	moderate	SOLA (no label recommen-dations) for aphid control in strawberries. Approved for control of aphids in many other crops	Good	sh	s	s	?	s, mummy mh, adults 1/2 wk
thiacloprid	Calypso	chloronicotinyl	long	SOLA on outdoor & protected strawberry for capsid control until Dec 05. Rosy apple aphid in apple.	Good	mh	?	?	?	mh adults ? wks

h harmful **mh moderately harmful** **s safe** **sh slightly harmful**

*** Chess WG has a SOLA for use on protected crops only, Plenum WG has a SOLA for use on outdoor crops only**

Table 5 Hazards, harvest intervals and spray information for insecticides approved for use on strawberry

	Hazards				Harvest interval (days)	Maximum number of sprays	Buffer zone width (m)*
	Anticholin-esterase?	Humans	Fish & other aquatic life	Bees			
bifenthrin	no	h, i	ed	ed	0	2 per year	18
chlorpyrifos	yes	h, i	ed	d	14	3 per year	18
nicotine	no	t	d	h	2	u	u
pirimicarb	yes	t, h	vt	le	3	u	u
pymetrozine	no	u	h	hr	12 weeks	3 per crop	u
thiacloprid	no	h	h	u	3	Maximum total dose 500ml product per year	30

h harmful
i irritant
d dangerous
ed extremely dangerous
hr high risk
le has little effect
u uncategorised/unclassified/unspecified
vt very toxic
t toxic
***** buffer zone distances are for broadcast air-assisted sprayers

Glossary of terms:

Acquisition:
Period of feeding needed for the aphid to ingest or 'acquire' the virus

Circulative:
Virus remains and reproduces within the aphid gut system

Inoculation access period:
Period of feeding for the aphid to pass the virus in to the plant

Latency period:
Time between aphid ingesting the virus and it then becoming established in the aphid gut system for subsequent infection to a host plant

Persistent:
Remaining within the aphid gut system

Replicative:
Virus particles replicate (ie increase in number) within the aphid vector's body and are not just carried on the mouthparts

Semi-persistent:
A virus that does not permanently infect the aphid vector, requires long periods of feeding to acquire, and many hours to successfully transmit. Note that strawberry plants once infected with viruses are permanently infected.

Transmission:
To pass on the virus to the plant

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