Apple blossom weevil (Anthonomus pomorum (Linnaeus))

Apple blossom weevil was one of the most destructive apple pests before the advent of insecticides. In the past it was uncommon in conventional commercial apple orchards as it was controlled very effectively with organochlorine insecticides. The last of these, HCH (Gammacol, Lindane), was withdrawn from use several years ago and apple blossom weevil has since been increasing in importance.

Adult apple blossom weevil

Although it is still uncommon in conventional commercial apple orchards, it is one of the most important pests in organic apple orchards. Apple is the normal host, but pear, quince and medlar are sometimes attacked. Post-hibernating adults show preferences for certain varieties (e.g. James Grieve) in mixed apple orchards but the relative susceptibility of different varieties has not been quantified adequately.

The pest is widespread and common in unsprayed apple orchards but uncommon and locally distributed in commercial orchards sprayed with conventional insecticides. The weevil often occurs in greatest numbers round the margins of apple orchards adjacent to woodland and hedgerows, which provide overwintering sites for the pest. The pest is thus more common in orchards in areas which are wooded and where there are organic, unsprayed or derelict orchards in the vicinity.

Capped blossoms caused by apple blossom weevil larvae

Most stages are readily recognised.

- Brown capped blossoms, formed after the larvae have nipped the petal bases to arrest their development, are the characteristic damage of this pest.
- Capped blossoms mostly do not develop into fruits but on some varieties (e.g. Fiesta) some fruits develop to harvest. These are malformed and flattened in shape.
- In orchards where the pest has not hitherto been seen, watch out for capped blossoms on trees at the edges of the orchard. This is the first sign that the pest is increasing. This should prompt assessment and treatment if necessary in subsequent years.
- The life cycle involves the weevil overwintering as an adult mainly in woodland and hedgerows adjacent to orchards and emerges in early spring to fly into apple orchards at around bud burst. The adult is strongly attracted to bursting apple buds.
- Assess the populations of adult weevils in orchards at risk in early spring at bud burst using the beating method. If 5 or more weevils are collected in a 50 beat sample, significant damage is likely to occur and insecticide treatment is justified.
- Similar damage may be caused by some other pests.

Control

There are some natural enemies of this pest but generally it is controlled by application of a spray of a broad-spectrum insecticide against adults at or shortly after bud burst, after the migration into the orchard has finished but before significant numbers of eggs are laid.

- This is usually at or before the mouse ear growth stage.
- Insecticides available currently have little effect on eggs or larvae in blossoms though sprays of insecticides in June and July may control newly emerged adults before they migrate to their overwintering quarters.
- Chlorpyrifos (Dursban etc.) is the only insecticide approved for use on apple and recommended by the manufacturer for control of apple blossom weevil. It is most effective if applied in warm weather conditions.
- However, thiacloprid (Calypso) has also been shown to be highly effective in trials in the Netherlands when applied against adults around bud-burst.
- Efficacy is improved by admixture with a non-ionic wetter, Synthetic pyrethroid insecticides are also highly effective but their use should be avoided as they are harmful to the orchard predatory mite *Typhlodromus pyri* and other natural enemies.
- Sprays of chlorpyrifos (Dursban etc.) or thiacloprid (Calypso) to control other pests in June are likely to control summer-emerged blossom weevil adults.

Insecticides approved for use on apple that are likely to control apple blossom weevil adults. Only chlorpyrifos (Dursban etc.) is specifically recommended by the manufacturer for control of apple blossom weevil

Choice of insecticides - efficacy factors

Active ingredient	Trade names	Class[1]	Recommended by the manufacturer for control of -	Safety to *Typhs*
chlorpyrifos	Dursban, etc.	OP	Apple blossom weevil on apple and pear, aphids, caterpillars, capsids, suckers, codling and tortrix moths, sawflies	safe
cypermethrin	Various products	pyrethroid	Aphids, suckers, capsids, caterpillars, codling and tortrix moths	harmful
deltamethrin	Decis etc.	pyrethroid	Aphids, suckers, capsids, caterpillars, codling and tortrix moths	harmful
thiacloprid	Calypso	chloronicotinoid	aphids	safe

Choice of insecticides - Safety factors

	Hazards[2]				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
chlorpyrifos	yes	h,i	ed	d	14	3	18
cypermethrin	no	h,i	ed	d	0	5	18
deltamethrin	no	h,i	ed	d	0	-	18
thiacloprid	no	h			14	2	30

Keys: [1]OP=organophosphorus insecticide

[2]d=dangerous, ed=extremely dangerous, h=harmful, i=irritant

Control in organic orchards

The apple blossom weevil is one of the most important pests in organic apple orchards. There are no effective chemical control methods which are permitted for use in organic apple production in the UK.

- In other European countries, early season sprays of pyrethrum or extract of the plant *Quassia amara* are used against adults.
- The former appears to be fairly effective but there are no approved formulations of pyrethrum in the UK.
- It is possible that a spray of rotenone (Derris) would be at least partially effective. However, the use of this insecticide in organic apple production has been suspended.

Further reading

Recognition

Adult

A small beetle, 3.5-6.0 mm long, with a long snout, dark brown to black, covered with brown, greyish and whitish hairs and mottled, with a V-shaped mark across the elytra and a prominent whitish spot between the elytra and thorax.

Egg

0.7 x 0.5 mm, oval, white and translucent.

Eggs are laid on an anther lobe inside the flower bud.

Larva

Up to 8 mm long, white with a dark brown head, leg-less, body yellowish when fully grown. Found in capped blossoms.

Pupa

4-5 mm long, pale yellow.

Found inside capped blossoms.

Apple blossom weevil pupa

Damage

- The main damage is destruction of blossoms.
- Brown capped blossoms, formed after the larvae have nipped the petal bases to arrest their development, are characteristic of this pest.

- Infested flowers mostly fail to develop and later fall from the tree.
- Light attacks may be of little importance and the pest may have a beneficial thinning effect. However, heavy infestations may destroy most or all of the flowers and crops may be devastated.
- On some varieties, the fruit of some infested flowers continues to develop until harvest. The fruits are malformed, flattened in shape and are distorted around the calyx.

Capped blossoms caused by apple blossom weevil larvae

Life cycle

Adults hibernate under tree bark, in cracks in posts, beneath debris or other suitable shelter. However, modern apple orchards offer few shelters and weevils often migrate in numbers to suitable places in adjacent woodland, hedgerows and ditches.

- The adults emerge very early in spring, in late February or March, flying to apple trees at about the time apple buds are breaking. Little flight activity occurs below 12ºC but most weevils migrate actively at 18ºC.
- The weevils feed on the buds on arrival. They are active mainly, though not exclusively, at night when most crawling, mating and egg-laying occurs.
- After mating, eggs are laid singly from bud-burst onwards, each inserted through a small puncture in the side of a flower bud which the female first makes with her rostrum. The egg is inserted with the ovipositor through the puncture in the side of the bud and is placed in a groove made by the female on an anther lobe.
- Eggs hatch within 10 days. The young larvae graze on the anthers and styles and then nip the base of the petals to form the familiar capped blossom.
- The larvae continue to feed on the flower parts and are full grown after about a month when they pupate within the shelter of the capped blossom.
- Adults emerge 2-3 weeks later. Newly emerged weevils reach their greatest numbers by mid-June feeding on the undersides of apple leaves for a few weeks.
- They then disperse to their winter hibernation sites. A few adults from the parent generation may also survive the winter.

Monitoring

Adults

The normal method of determining the risk of damaging infestation by apple blossom weevil is to assess populations of adults shortly after emergence at bud-burst in March using the beating method.

- For each beat sample, a branch is tapped sharply with a beater (a 0.25 m length of stiff hose to prevent damage to the branch) over a 0.25 m^2 collection tray.
- At least 25 (preferably 50) beat samples should be taken per orchard and the total number of weevils collected should be recorded.
- The economic threshold is taken to be 5 weevils in a 50 beat sample, but this may be too high when the quantity of blossom present is light.

Capped blossoms

Once capped blossoms are visible, the damage is done and it is too late to control the pest with insecticides to prevent damage in the current year.

- However, a watchful eye for capped blossoms should be maintained, especially at the edges of orchards next to woodland or near unsprayed apple trees.
- The pest is absent from most commercial orchards sprayed with conventional insecticides and the appearance of capped blossoms will be the first indications that the pest is starting to establish.
- The presence of damage one season should prompt detailed assessment of the pest in subsequent seasons.

Damage to fruits during the growing season, at harvest or during grading

- If significant malformation damage to fruits is seen one season, treatment is likely to be justified the next season to avoid damage intensifying.

Forecasting

The migration of the flight of apple blossom weevil adults occurs in March on warm, sunny days when daytime temperatures reach 12-20 °C.

Other pests with which apple blossom weevil may be confused

Tortrix moth caterpillars can occasionally form a capped blossom rather like the apple blossom weevil.

Apple bud weevil (Anthonomus piri) The adult of the apple bud weevil is very similar in appearance to the adult apple blossom weevil, but is a lighter, brown colour, and lays its eggs in the autumn and early spring.

- The apple bud weevil is local and rare in the UK and until recently was only recorded on apple though a recent local outbreak has occurred on pear in north Kent.
- It is an important pest of pear in continental Europe.
- The larva infests buds which are hollowed out remaining as dead husks in which the larva is found.

Apple twig cutter (Rhynchites caeruleus): A locally common weevil that occurs on apple but the adult is metallic blue in colour and appears much later in May and June causing characteristic shoot severing damage.

Apple fruit rhynchites (Rhynchites aequatus): The adult weevil is reddish brown occurring in May to July and sometimes feeds on developing apple fruitlets drilling small holes in the flesh causing characteristic damage symptoms.

Adult Rhynchites weevil

Control methods

Chemical control

The usual method of control of apple blossom weevil is to apply a spray of a broad-spectrum insecticide against adults at bud burst when most adults have migrated into the apple crop but before significant egg-lying has occurred.

- The organochlorine insecticides DDT and HCH were traditionally used for this purpose and were highly effective but have now long been withdrawn from use.
- Chlorpyrifos (Dursban etc.) is the only insecticide specifically recommended for control of apple blossom weevil on apple and pear.
- Synthetic pyrethroids such as cypermethrin (various products) or deltamethrin (Decis) are also highly effective but their use should be avoided as they are harmful to the orchard predatory mite *Typhlodromus pyri* and a wide range of other natural enemies.
- Pirimicarb (Aphox etc.) and fenoxycarb (Insegar) are ineffective.
- However, the eggs from female apple blossom weevils that have fed on buds treated with diflubenzuron (Dimilin) often don't hatch. Thiacloprid (Calypso), though only recommended for rosy apple aphid control on apple, is also very effective against apple blossom weevil. Best results are obtained with this product when it is used in admixture with a non-ionic wetter (e.g. Activator 90).
- The spray should be applied in good, warm weather conditions if possible. Medium to volumes are recommended to achieve good cover of the bark.
- A beat sample should be taken after treatment to ensure that good control of adults has resulted and that no further invasion has occurred.
- It is probable that sprays of chlorpyrifos (Dursban etc.) or thiacloprid (Calypso) applied in June and July to control other pests also incidentally control newly emerged apple blossom weevil adults feeding on foliage before they migrate to their winter hibernation sites.

Insecticide resistance

Resistance of apple blossom weevil to insecticides is not known and is unlikely to occur.

Cultural control

Young, dwarf apple trees have smooth bark, which provides few overwintering sites for the weevil in the orchard. Moreover, well-managed orchards have little leaf litter in which the weevils can overwinter, so most weevils overwinter outside the orchard in nearby woodland and hedgerows. The weevil is less of a problem in orchards that are not adjacent to woodland or hedgerows.

- Loss of even quite a high proportion of buds may be of limited importance on apple trees that have high numbers of apple buds and on varieties where damaged flowers do not continue to develop into mature fruits.
- Good tree management and nutrition will greatly reduce the impact of this pest.
- In organic orchards where the pest is especially troublesome, providing adequate nitrogen to the trees is important to maintain fruit bud numbers and quality.
- On a limited scale, it might be feasible to remove and destroy capped blossoms before the weevil completes its development and emerges. This could be done when hand thinning of fruitlets is done. This should reduce the risk of allowing damaged fruits to mature.
- On a limited scale, it might be possible to provide artificial hibernation sites for adults (e.g. trunk bands) in June before the weevil moves to its hibernation quarters. The artificial hibernation sites could then be removed and the weevils destroyed. This approach probably hasn't been tried and may not be very effective.

Natural enemies

The apple blossom weevil is eaten by small birds such as tits but the most important natural enemies are two species of parasitic wasp. Because small numbers of apple blossom weevil can be tolerated economically, these parasitic wasps might be important natural enemies.

Parasitic wasps

The ichneumon parasitic wasp *Scambus pomorum* is a common parasite of apple blossom weevil.

- The adult female parasitic wasp pierces the capped blossom with her ovipositor, stings the apple blossom weevil larva and injects a paralysing poison. She then deposits a transparent, elongate egg onto the larva.
- The egg hatches in a few days and the parasite larva attaches itself to the dorsal side of the host larva with its mouth parts immersed within the tissue of the latter. The fully-grown larvae are elongate and fusiform in shape, narrowing towards the extremities.
- There are four larval stages. Eight to ten days after hatching, the fully grown parasite larva leaves the remains of the host to spin a thin silken cocoon within the cavity of the capped blossom.
- Pupation is completed in 4-5 days. The pupa turns black and the adult wasp emerges about 11 days later, about 2 weeks later than adults of the apple blossom weevil.
- Up to 50% parasitism has been recorded. *Scambus pomorum* does not have a second generation. After emergence, the females appear to be in a state of reproductive diapause.
- The adults feed on a wide range of types of larvae (moths, flies, sawflies) throughout the summer and overwinter.

The other parasitic wasp is the braconid *Syrrhizius delusorius* which parasitises the adult apple blossom weevil. This parasite is believed to have 2 generations a year.

- It overwinters as a small (about 1.2 mm long) larva in the abdomen of the adult weevil.
- In May, the full-grown larva leaves the host through a small hole it makes in the exoskeleton of its host.
- The emerging larva is very active and spins a cocoon within 24 hours within which it pupates.
- The adult wasp emerges a few weeks later in synchrony with the emergence of adult weevils.
- The female parasite climbs onto the back of the weevil and stings into the abdomen under the wing cases.
- Females become excited when offered a capped blossom, even when empty, indicating the way the host is located.

Biological control

No specific biological control measures have been developed. The natural enemies of apple blossom weevil, especially the parasitic wasps, should be fostered by avoiding the use of harmful insecticides (see above). Nesting boxes could be provided for tits which might help reduce populations.

Biotechnological control

It has been shown that the weevil is strongly attracted by host plant volatiles produced by bursting apple buds. Some of the terpenoid chemical compounds involved have been identified. It might be possible to exploit these for monitoring or control of the pest but such methods have not been investigated or developed as yet. Work is in progress at East Malling Research to identify a sex pheromone of apple blossom weevil

Further reading

Duan, J. J., Weber, D. C., Hirs, B., & Dorn, S. 1996. Spring behavioural patterns of the apple blossom weevil. *Entomologia Experimentalis et Applicata* 79, 9-17.

Kalinova, B., Stransky, K., Harmantha, J. Otvrtecka, R. & Zd'arek, J. 2000. Can chemical cues from blossom buds influence cultivar preference in the apple blossom weevil

(*Anthonomus pomorum*)? *Entomologia Experimentalis et Applicata* 95, 47-52.

Miles, H. W. 1923. Observations on the bionomics of the apple blossom weevil, *Anthonomus pomorum* Linn. *Annals of Applied Biology* 10, 348-369.

Morris, M. G. 1977. The British species of *Anthonomus* Germar (Col., Curculionidae). *Entomologists Monthly Magazine* 112, 19-40.

Reijbroek, P. 1983. The relation between attack and damage by the apple blossom weevil, *Anthonomus pomorum* L. *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* 48, 287-291.

Zizp, J. P. & Blommers, L. H. M. 1992. *Syrrhizus delusorius* and *Scambus pomorum*, two parasitoids of the apple blossom weevil. *Proceedings of Experimental and Applied Entomology, N. E. V. Amsterdam*, 3, 46-50.

Apple grass aphid (Rhopalosiphum insertum (Walker))

Apple grass aphid is the most common aphid species on apple but it only causes minor damage to commonly grown apple varieties. Some apple varieties are more sensitive e.g. Jonathan. The life cycle involves two hosts. Apple, pear and quince are the winter hosts of apple-grass aphid and grasses (especially annual meadow grass) are the summer hosts. The migration to the summer host in May-June is obligate and so infestations do not persist on fruit trees during the summer.

Apple grass aphid attended by black ants

It is widespread and abundant in apple orchards in spring, especially when the previous summer has been wet so favouring the growth of grasses.

The aphid hatches at bud-burst to early green cluster from overwintered eggs on the bark and develops on the rosette leaves and amongst blossom trusses causing minor curling damage of leaves if large populations occur in early spring before or during early blossom. Damage is rarely important unless populations are very high. There is little risk of damage from this pest after mid blossom as winged forms develop which migrate to grass during and after blossom.

Green apple aphid and common green capsid both may be present and causing damage but are readily distinguished.

The severity of infestation by apple grass aphid should be determined in each orchard by monitoring in spring when the usual pre-blossom pest assessment is done.

- At least two blossom trusses should be inspected on at least 25 trees per orchard.
- Presence of the aphids in a particular truss is often indicated by slight leaf distortion and/or the presence of cast skins on the surface of the rosette leaves.

Chemical control

An insecticide treatment for the aphid should be applied **before** blossom if the economic threshold of 50% of blossom trusses infested with 5 or more aphids is exceeded. Insecticide sprays should only be applied for this pest **if strictly necessary** as it provides an early food source for natural enemies of other more damaging species.

- Several insecticides are approved for control of aphids on apple and pear but if apple grass aphid is the only pest that needs to be controlled, pirimicarb (Aphox etc.) or flonicamid (Teppeki, Mainman) are the preferred choices in conventional orchards as they are selective and partially systemic.
- The neonicotinoids thiacloprid (Calypso), acetamiprid (Gazelle) and thiamethoxam (Centric) are also approved for control of aphids on apple though they can be a little slow acting in cool conditions.
- They are systemic and are highly effective against aphids. They will give excellent control of apple grass aphid and several other pests such as capsids and sawfly.
- They have little effect against caterpillars and thiacloprid (Calypso) and acetamiprid (Gazelle) are ineffective against woolly aphid.
- Note that thiamethoxam (Centric) is dangerous to bees and **must not be used during flowering.**
- However, if winter moth or tortrix moth caterpillars need to be controlled, chlorpyrifos (Dursban etc.) is likely to be the best choice.
- Use of synthetic pyrethroids, which are harmful to natural enemies, should be avoided.

Insecticides approved for control of aphids on apple

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of -	Safety to *Typhs*
acetamiprid	Gazelle	neonicotinoid	broad-spectrum, systemic	Aphids and Whitefly	safe
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars, sawfly, capsids etc.	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids, capsids,	harmful

				caterpillars, codling & tortrix moths, sawflies, apple sucker	
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
fatty acids	Savona	soap	broad spectrum	Aphids, scale insects	harmful
flonicamid	Teppeki, Mainman	neonicotinoid	selective	Aphids and woolly aphid	safe
nicotine*	various	alkaloid	broad spectrum	Aphids including woolly aphid, caterpillars, sawflies	harmful
pirimicarb	Aphox etc.	carbamate	selective aphicide, trans-laminar	Aphids	safe
thiacloprid	Calypso†	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids and sawfly, though not caterpillars or woolly aphid)	safe
thiamethoxam	Centric	neonicotinoid	Broad-spectrum, systemic	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe

Choice of insecticides - Safety factors

	Hazards				**Harvest interval (days)**	**Max. no. sprays**	**Buffer zone Width (m)**
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
acetamiprid	no	u	h	u	14	2	20
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
fatty acids	no	u	h	u	0	u	sm
flonicamid	no	u	h	u	21	3	sm

nicotine*	no	t, h	d	h	2	u	sm
pirimicarb	yes	t, c	h	-	3	u	sm
thiacloprid†	no	h, i	h	h	14	2	30
thiamethoxam	no	h	h	d	14	2	sm

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, t=toxic, c=closed cab required for air assisted sprayers, sm=statutory minimum of 5 m for broadcast airassisted sprayers u=uncategorised/unclassified/unspecified

† not approved for use on pear

*approval for use and storage of all products containing nicotine is allowed only until 8 June 2010

Control in organic orchards

Chemical control of apple grass aphid is usually not attempted in organic orchards because the pests only causes minor damage which is tolerated.

- Emphasis should be placed on cultural control measures such as the provision of artificial refuges for earwigs and lacewings and of flowering herbs in and around the orchard to encourage predatory insects.
- High volume sprays of fatty acids (potassium soap) (Savona) could be applied when damaging infestations develop if necessary on more sensitive varieties.

Further reading

Life cycle

- Overwintered eggs on the bark of apple trees hatch in spring by the green cluster growth stage.
- The nymphs feed on the undersides of the rosette leaves and amongst the flower buds sometimes invading the flowers during bloom.
- The first generation is wingless but the second generation is winged.
- The first winged aphids migrate to grasses in mid-May during blossom.
- Populations on apple then decline rapidly.
- In the autumn, winged females return to fruit trees and their wingless progeny (the egg-laying females) mate with winged males returning from grasses.
- Eggs are deposited on spurs and branches, just before leaf fall.

Recognition

Egg
Shiny black and found on the bark of apple trees on rough bark around buds.

Adult
Yellowish green with darker green longitudinal stripes down the body.
Honey tubes short, pale green and flanged at the tip.

Other pests with which the pest may be confused

Green apple aphid: The other aphid species that occurs commonly on apple which has a green colour. However, the green apple aphid is uniformly green and has black, moderately long honey tubes. It tends to form dense colonies in extension growth in mid-late summer.

Common green capsid: Nymphs of the common green capsid are green in colour and superficially resemble apple grass aphid. They also occur at a similar time. However, capsid nymphs are active and fast moving and occur as individuals rather than in colonies. Capsid nymphs cause distinct damage to foliage and fruit.

Monitoring

The severity of infestation of each apple orchard by apple grass aphid should be determined when the pre-blossom pest assessment is done at the green cluster to pink bud growth stage.

- Inspect at least two blossom trusses on each of at least 25 trees per orchard for infestation by the aphid.
- Presence of the aphids in a particular truss is often indicated by slight leaf distortion and/or the presence of cast skins on the surface of the rosette leaves.
- An insecticide treatment for the aphid is justified if the economic threshold of 50% of blossom trusses infested with 5 or more aphids is exceeded.
- Counts of the wingless aphids on apple trees in late October give a good indication of the likely infestation the following spring.
- An average of one aphid or fewer per leaf from samples of 20 leaves examined on 8-10 trees across the orchard indicates a potentially light spring infestation.

Forecasting

Useful forecasting models have not been developed for apple grass aphid. However, the pest is usually most abundant when there has been plentiful rainfall in summer and

autumn the previous year to encourage growth of grass, the aphid's summer host.

Cultural and biological control

There are few specific cultural controls for apple-grass aphid. Natural enemies should be encouraged by avoiding the use of broad-spectrum insecticides and by providing flowering plants in and around the orchard. Artificial refuges can be provided for predators. High nitrogen levels in the tree favour apple grass aphid.

Natural enemies

Predatory insects and spiders

- A wide range of predatory insects, including anthocorid, mirid and nabid bugs, ladybird adults and larvae, hoverfly, predatory midge and lacewing larvae and spiders feed on apple grass aphid in spring.
- The aphid often provides an important early food source which increases predator numbers for natural regulation of other pest species.
- Spiders and earwigs are more important as natural enemies of the returning migrants and their offspring in the autumn.

Parasitic wasps

- The parasitic wasp *Monoctonus mali* is the most important parasitoid of apple grass aphid, though there are several other less important species including *Ephedrus persice, Ephedrus validus, Praon necans, Praon volucre* and *Trioxys auctus*.
- The parasites lay their eggs (usually singly) in the body of the aphid which continue to feed during the early stages of development of the parasite.
- The parasites eventually pupate within or beneath the skeleton of the aphid forming a so-called 'aphid mummy'.
- *Monoctonus mali* is a host-specific parasite which has two generations on apple grass aphid in spring before entering a summer diapause when its host begins to migrate to grasses.
- Although parasitic wasps are common natural enemies of apple grass aphid, they are not usually abundant enough to greatly reduce aphid populations.

Biological control

Biological control approaches have not been developed for apple grass aphid.

Further reading

Barbagallo, S., Cravedi, P, Passqualini, E, Patti, I, & Stroyan, H. L. G. 1997. Aphids on the principal fruit bearing crops. Bayer, Milan.123pp

Minks, A. K. & Harrewijn, P. 1987. Aphids, their biology, natural enemies and control. World Crop Pests, Volumes 2A, 2B and 2C. Elsevier, Amsterdam.

Apple leaf midge (Dasineura mali (Keiffer))

Apple leaf midge is a widespread and abundant but usually minor pest of apple present in all apple orchards, often on most trees. Apple and Malus sp. only are infested. All apple varieties are susceptible. Trees with vigorously growing shoots are attacked most heavily. A similar species, the pear leaf midge, attacks pear.

Leaf midge attacks young leaves, mainly in growing points, but can also attack rosette leaves. Larvae cause the edges of leaves to roll tightly round themselves to form characteristic leaf curls. Shoot growth is reduced. This is usually of little consequence in established orchards but is more important on nursery stocks and newly planted trees.

Occasionally, very severe attacks occur in established orchards, notably Bramley. Photosynthetic leaf area is greatly reduced, sometimes by over 50%, and this adversely affects fruit size and fruit bud formation.

Apple leaf midge larvae

The lifecycle involves 3-4 generations per year, the first around blossomtime but the larval stage is the most readily recognised. Eggs are brown and cigar shaped and laid amongst hairs in the very tiniest leaves in the growing points. They can just be seen with the naked eye but use of a hand lens is desirable.

Numbers of eggs should be monitored weekly in a representative orchard on the farm if the pest is to be managed either with insecticides (i.e. on nursery stocks) or by control by its natural enemy, the parasitic wasp Platygaster demades in orchards.

The female-produced sex pheromone of apple leaf midge has been identified by East Malling Research and the Natural Resources Institute and is highly attractive to apple leaf midge males.

Sex pheromone traps are available from East Malling Research. The traps should be deployed in nurseries (or plantations where chemical control of leaf midge is to be applied) in early spring at the green cluster growth stage and monitored weekly through the season.

- The height of trap deployment is critical and a standard height of deployment of 0.5m is recommended. The lures last a season in the field.
- Unused lures should be stored in a freezer where they will remain viable for many years, or alternatively in a fridge where they will last 3 years or more.
- A nominal threshold of 30 midges per trap per week is proposed for timing sprays of insecticide (e.g. a synthetic pyrethroid in the UK).

Apple leaf midge damage

Chemical control

A series of sprays at 7 day intervals is likely to be required. Good control of the first generation should result in a reduced attack in the later generations.

- None of the insecticides approved for use on apple are recommended by the manufacturer for control of apple leaf midge and there is currently no satisfactory control for this pest.
- The pest appears to be resistant to chlorpyrifos (Dursban etc.) though chlorpyrifos may have limited activity against adults and eggs.
- Synthetic pyrethroids (bifenthrin (Talstar), cypermethrin (various products) and deltamethrin (Decis)

- Synthetic pyrethroids (bifenthrin (Talstar), cypermethrin (various products) and deltamethrin (Decis) are effective if targeted against adults and eggs as they hatch. They are ineffective when used against larvae in leaf curls. However, their use should be avoided except possibly on nursery stock, as they are harmful to the predatory mite Typhlodromus pyri and to the parasitic wasp Platygaster demades, which is the key natural enemy of this pest (see below) and will do more harm than good in the long run.

Biological control

The parasitic wasp Platygaster demades is the key natural enemy of apple leaf midge and will reduce populations to low, tolerable levels if allowed to establish and thrive. The parasite occurs naturally in the UK but is often absent or present at only very low levels in commercial orchards as it is sensitive to broad-spectrum insecticides.

- It can be introduced on infested leaves from other orchards if necessary. The parasite lays its eggs in the eggs of the apple leaf midge.
- The adult parasite is synchronised with its host but is vulnerable to insecticides including to residues on leaf surfaces.
- To foster the parasite, the use of broad-spectrum insecticides should be avoided during the egg-laying period of the leaf midge. More selective insecticides such as Bacillus thuringiensis, diflubenzuron (Dimilin), pirimicarb (Aphox etc.) and fenoxycarb (Insegar) are less likely to be harmful to the parasite and these insecticides should be used for pest control at critical times if possible.

Control in organic orchards

Emphasis should be placed on cultural and biological control methods as there are no known effective chemical control methods for leaf midge in organic apple production.

Further reading

Apple leaf midge eggs

Adult Platygaster demades, the parasite of the apple leaf midge

Life history

Eggs are laid amongst hairs in the youngest tiny leaves in shoot tips, often in large numbers. These hatch in 3-5 days and the larvae feed on the upper epidermis causing the margins to curl and roll round themselves.

Larvae are full-grown in 2-3 weeks and then drop to the ground to pupate in silken cocoons in the soil. Lack of rain may delay the exit of the full-grown larvae from the hardened leaves and hence lengthen the development period. Sometimes, a mass exodus from the leaf rolls by large numbers of larvae occurs when a long period of dry weather is terminated by a thunder storm.

There are typically three generations per year, larvae of the third generation overwintering in cocoons in the soil before pupating in the spring and emerging in late April or May, often during or shortly after bloom.

Recognition

Adult
Very small, 1.5-2.5 mm long, delicate fly, with broad, slightly hairy, wings with little venation. Antennae long, beaded with whorls of hairs in male, plainer in females. Females have a red abdomen. Usually seen resting or ovipositing in the shoot tips of apple.

Larvae
2.5-3 mm long, maggot-like larvae. Translucent-white when young but becoming pink or orange when mature. Dorso-ventrally flattened with a bi-lobed sternal spatula ('breast bone'). Found in the tight leaf rolls they cause.

Eggs
Tiny, cigar–shaped and reddish or brown. Found amongst hairs in the very youngest leaves in shoot tips.

Other pests with which the pest may be confused

Tortrix moth caterpillars also cause leaf rolls but tortrix caterpillars cannot be confused with apple leaf midge larvae.

Natural enemies and biological control

Natural enemies

Predators
Birds, probably tits, are reported to predate larvae, causing incidental damage to the leaf rolls. Predatory anthocorids and mirids are important natural enemies of apple leaf midge larvae in leaf rolls. It is probable that larvae and cocoons in the soil are preyed upon by predatory ground beetles.

Parasitic wasps
The parasitic wasp Platygaster demades is the most important natural enemy of apple leaf midge. The adult wasp is minute and lays its eggs in those of the midge. The occurrence of the adult parasite is closely synchronised with its host.

- Usually one, sometimes two but up to three or four eggs may be deposited in one host egg. The parasite does not hatch until after the egg of its host has hatched.
- The tiny globular parasite larvae are found in the anterior end of the larvae, attached possibly to the salivary glands. Development is slow until the host larva is fully-grown.
- The life cycle of the parasite is poorly understood but there are at least two generations, possibly three or four per annum.
- High levels (>80%) of parasitism by Platygaster demades have been shown to occur in Integrated Pest Management in other European countries and the parasite is considered to be the key natural enemy of the leaf midge.
- The adult parasite is believed to be sensitive to broad-spectrum insecticides. Leaf midge populations have been shown to decline where broad-spectrum insecticides are not used and the parasite is allowed to establish.

Another larval parasite, Torymus chlomerus, also occurs occasionally. It is an ectoparasite, which in the larval state lives outside but next to its host.

- The larvae are distinctive and sparsely clothed with spines. They usually occur singly in midge leaf rolls.
- One Torymus larva can consume 2-5 leaf midge larvae (and could be considered to be a predator).

Biological control

In some young and established orchards, notably Bramley, severe outbreaks of leaf midge occur from time to time, greatly reducing the area of photosynthetic foliage and probably reducing fruit size and fruit bud formation. These outbreaks occur because there are no suitable chemical control methods for apple leaf midge at present in the UK and because the parasite that regulates populations of the midge, Platygaster demades, is absent or at low levels only in most commercial apple orchards because of indiscriminate spraying with broad-spectrum insecticides.

In order to establish the natural balance, the priority should be to establish and increase the parasite Platygaster demades. The parasite occurs naturally in the UK.

The adult, which has a distinctively shaped abdomen and wing venation, can sometimes be seen in the shoot tips of apple amongst clusters of leaf midge eggs. However, accurate identification is for the specialist entomologist as there are many species of parasitic wasp of similar appearance.

The degree of parasitism of the population is best determined by dissecting mature larvae. Each larva is immersed in a small pool of water in a watch glass under a binocular microscope.

- A pair of dissecting needles are drawn in opposite directions across the anterior (head end) of the larva causing the body to rupture and any parasite larvae to burst out into the water along with some of the body contents.
- The larvae are globular and there may be one, two or several inside a midge larva.
- Dissection is best done in a laboratory by an experienced entomologist.

Where the parasite is totally absent from an orchard it may be possible to introduce it from another orchard where it is abundant. This was done in an experimental orchard where the parasite was absent at East Malling in the 1990s.

- Leaf rolls containing mature (pink-orange) leaf midge larvae, 25% of which were parasitised by Platygaster demades, were collected from an unsprayed orchard at Marden in summer and one leaf roll was lodged in the foliage of the orchard where the parasite was to be introduced. The parasite was present at low levels the following year and gradually increased in subsequent years. However, it was not possible to determine whether the parasite population developed from the one introduced.
- In the Netherlands, the parasitoid has been found to greatly reduce leaf midge populations, though irregular flare-ups of the midge have been found to occur. These are followed by an increase in the parasitoid which then reduces populations of the pest.

The adult parasite is believed to be particularly sensitive to broad-spectrum insecticides.

- Their use while the adult parasite is active, i.e. during the egg-laying period of the leaf midge, should be avoided.
- Egg laying by the midge should be monitored closely. Use of broad-spectrum insecticides should be avoided for a week or two when eggs are numerous.
- Some insecticides, notably Bacillus thuringiensis, diflubenzuron (Dimilin), fenoxycarb (Insegar), pirimicarb (Aphox) are likely to be less harmful to the parasite.
- These would be a better choice if they are effective against the target pest and use of an insecticide at the critical time is essential.

Biotechnological control

A powerful sex pheromone, emitted by the female midge shortly after emergence to attract males for mating has recently been identified by East Malling Research and the Natural Resources Institute. However, attempts to exploit the pheromone for control of the midge by mating disruption, attract and kill or mass trapping have not been successful to date.

Cultural control

Cultural control options are limited for apple leaf midge. Attacks tend to be more severe where trees have abundant vigorous shoot growth. Ensuring that tree growth is not excessively vigorous will prevent populations increasing.

- Removal of extension growth and watershoots by summer pruning when eggs and young larvae are numerous in the shoots may reduce populations subsequently but such removal between generations may cause more intensive damage to the remaining foliage by the next generation.
- Fostering high populations of predatory ground beetles by providing tussock grass in the alleyways may be beneficial.
- Cultivation of the soil under the trees where the larvae form cocoons to pupate may also be beneficial though this has not been demonstrated. However, such cultivation might have adverse effects on natural enemies such as earwigs.

Monitoring using pheromone traps

The female-produced sex pheromone of apple leaf midge has been identified by East Malling Research and the Natural Resources Institute and is highly attractive to apple leaf midge males.

Sex pheromone traps are available from East Malling Research. The traps should be deployed in nurseries (or plantations where chemical control of leaf midge is to be applied) in early spring at the green cluster growth stage and monitored weekly through the season.

The height of trap deployment is critical and a standard height of deployment of 0.5 m is recommended. The lures last a season in the field. Unused lures should be stored in a freezer where they will remain viable for many years, or alternatively in a fridge where they will last 3 years or more.

Identification of midges in trap

- Two winged fly, body about 2 mm long, abdomen dark/black in colour.
- Wings sparsely clothed with short dark hairs, very few veins (only 3 are easily visible, the two anterior ones reaching the wing margin).
- The first and second wing vein reach the wing margin anterior to and posterior to its apex, so that there is a lobe (see right hand diagram below).
- Long legs, often broken on sticky bases, with red pools of haemolymph.
- Males have a pair of claspers on rear of abdomen (Females, which are not attracted by the pheromone, have a long protractible ovipositor).
- Antennae long, filiform and beaded. Conspicuous whorls of hairs on each segment. Antennae are

curved back like long horns.

Apple leaf midge sex pheromone monitoring trap

- If other midge species caught in interesting or consistent numbers, save and photograph any interesting specimens. Do not attempt to remove them from the glue. Send to Jerry Cross at East Malling Research for identification.

Monitoring experiments conducted in several orchards in the UK, New Zealand and Italy demonstrated a linear relationship between the numbers of midges captured in a pheromone trap for a particular generation and the numbers of galls that developed in the crop for that generation subsequently:

Apple leaf midge males on pheromone trap sticky base showing identification features described above

Relationship between total catch per generation of first or second generation apple leaf midge males in standard sex pheromone traps and the number of galls formed per ha for that generation subsequently. [Best fit linear regressions on a log-log scale through the origin (dashed line) or unconstrained (solid line) are included]

The relationship indicates that each male midge caught in a trap for a particular generation corresponds to approximately 137 galls being formed per hectare subsequently for that generation, providing that there are sufficient shoots and tender young leaves present to accommodate them. Clearly the proportion of shoots and leaves galled per hectare will depend on the numbers of shoots and leaves present in the particular orchard but knowledge of these parameters should allow simple estimates to be made.

For practical purposes, a nominal threshold of 30 midges per trap per week is proposed for timing sprays of insecticide (e.g. a synthetic pyrethroid in the UK). A series of sprays at 7 day intervals is likely to be required. Good control of the first generation should result in a reduced attack in the later generations.

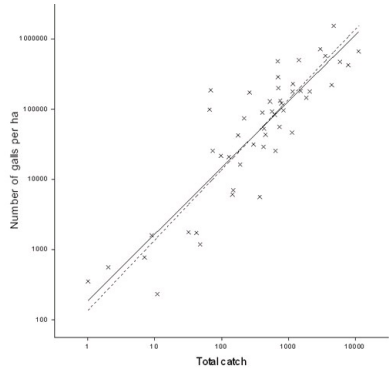
In most established orchards, the leaf midge is tolerated and the abundance of the pest is not monitored. However, monitoring of the timing of occurrence of eggs is beneficial for two reasons;

1. it indicates when application of broad-spectrum insecticides should be avoided so that establishment of the parasitic wasp Platygaster demades, a key natural enemy of the leaf midge is not impeded.
2. it indicates when sprays of broad-spectrum insecticides, which are active against adults, eggs and neonate larvae, should be applied for control of the pest on nursery trees.

Apple leaf midge males on pheromone trap sticky base showing identification features described above

Egg monitoring: Eggs are laid mainly on the tiny new leaves in shoot tips. Egg-laying of each generation generally occurs over a clearly defined period of a week or two, though the egg-laying period of the third generation becomes less distinct later in summer.

- Monitoring of the occurrence of eggs of the apple leaf midge should ideally be done weekly, more frequently at key times.
- It is sufficient to look at one representative part of an orchard per farm, choosing an early site for early warning of the egg-laying period.
- The growing points of several shoots in sheltered parts of the tree should be examined for the eggs.
- Often the female leaf midge can be seen in the act of oviposition.
- A rough count of the number of eggs should be made.



Leaf curling damage: Each time a pest or disease assessment is made in the orchard, a note should be made of the age of the youngest leaf in the shoots which has damage.

- If a larval attack is in progress, the youngest expanding leaves will show damage.
- Between generations, the youngest leaves will not be damaged. This will help indicate when the next generation is likely to occur.
- The occurrence of groups of damaged leaves of different ages in shoots shows a record of successive generations of larval attack.

Forecasting

Forecasting models for apple leaf midge have not been developed though it would be useful to develop temperature-based phenological forecasting models to predict the timing of occurrence of the start of egg laying in spring and the timing of successive generations.

Chemical control

None of the insecticides approved for use on apple in the UK are recommended by the manufacturer for control of apple leaf midge.

- The midge appears to be resistant to chlorpyrifos (Dursban etc.) and other organophosphorus insecticides which were traditionally used against the pest (dimethoate, fenitrothion, heptenophos, phosalone) are no longer available.
- The pest is evidently not controlled by the new chloronicotinyl insecticide thiacloprid (Calypso).
- Broad-spectrum pyrethroid insecticides (bifenthrin (Talstar), cypermethrin (various products) or deltamethrin (Decis etc.) are likely to be effective against leaf midge, but their use should be avoided unless absolutely necessary (e.g. on nursery trees).

Application should be timed to coincide with the egg-laying period because they are likely only to be effective against adults and young larvae as they hatch from eggs. Once the larvae are enclosed in the leaf rolls, they are very difficult to control with insecticides.

- Pyrethroid insecticides are contact acting only.
- They are harmful to the orchard predatory mite Typhlodromus pyri and many other beneficial insects including the parasite Platygaster demades which is an important natural enemy of apple leaf midge.
- For these reasons, they should only be used as a last resort and outbreaks of apple leaf midge should be tolerated.

Resistance to insecticides

Resistance to organophosphorus insecticides has been shown to occur in other countries and almost certainly occurs in the UK. This explains the increase in prevalence of this pest in recent years.

Further reading

Cross, J. V. & Jay, C. N. 2000. Exploiting the parasitoids Lathrolestes ensator and Platygaster demades for control of apple sawfly and apple leaf midge in IPM in apple orchards. Proceedings of 5th International Conference on Integrated Fruit Production, Lleida, Spain, October 2000. IOBC/WPRS Bulletin, 5pp.

J V Cross and D R Hall. Exploitation of the sex pheromone of apple leaf midge Dasineura mali Kieffer (Diptera: Cecidomyiidae) for pest monitoring: 1. Development of lure and trap. Crop Protection.

Jerry V. Cross, David R. Hall, Peter Shaw, Gianfranco Anfora. Exploitation of the sex pheromone of apple leaf midge Dasineura mali (Kieffer) (Diptera: Cecidomyiidae): 2. Use of sex pheromone trap for pest monitoring. Crop Protection.

Barnes, H. F. 1948. Gall midges of economic importance. Volume 3. Crosby Lockwood, London 184pp.

Todd, D. H. 1959. The apple leaf curling midge, Dasineura mali Kiefer, seasonal history, varietal susceptibility and parasitism. New Zealand Journal of Agricultural Research 2, 859-869

Apple Rust Mite (Aculus schlechtentali (Nalepa))

Apple rust mite is an important secondary pest of apple. A similar species, the pear rust mite, is an important and frequently damaging pest of pear.

Apple rust mite is seldom a problem in orchards where the orchard predatory mite, Typhlodromus pyri, is established. The predatory mite should be introduced, by transferring summer prunings in summer to newly planted orchards and to orchards where it is absent.

Pesticides harmful to the orchard predatory mite should not be used except as a last resort, as they cause outbreaks of rust and spider mites.

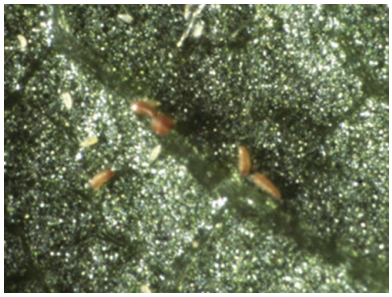
Rust mites are minute but can be seen with a x20 hand lens and are then readily recognised. They have a simple life cycle, overwintering behind buds in the previous season's extension growth. Monitoring the number overwintering behind buds in the previous season's extension growth is important in orchards where a satisfactory and stable balance between the mite and the orchard predatory mite has not been established.

They invade rosette leaves at bud burst and green cluster, causing shrivelling and puckering damage to the outer rosette leaves if present in high numbers.

They colonise the outer surface of the receptacle during flowering and the surface of young fruitlets round the calyx during early fruitlet development. This damage is most important and occurs at low to moderate population densities (1 mite per flower or young fruitlet).

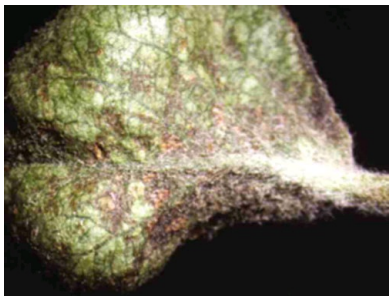
Feeding on developing fruitlets causes russeting round the calyx and on the cheek of the fruit.

Feeding on the undersides of leaves in summer causes browning.



Apple rust mite on leaf

Overwintering apple rust mite in crescent of hairs behind bud



Apple rust mite damage to Bramley rosette leaf at mouse ear

Russeting damage to fruits caused by apple rust mite

Chemical control

- Only diflubenzuron (Dimilin) is specifically recommended for control of apple rust mite but it is at best only partially effective and is unlikely to control severe infestations adequately.
- A programme of sprays sulphur (various products) at reduced rate (3-5 kg a.i. / ha), applied to control mildew on apple, will suppress rust mite and fruit tree red spider mite. Some apple varieties are sulphur shy (consult the label for details) but are often safe at low rates. However, multiple sprays of sulphur are likely to be harmful to the orchard predatory mite, so such an approach is not ideal.
- Fenpyroximate (Sequel) is recommended for control of fruit tree red spider mite on apple and will also give good suppression of rust mite.
- Bifenthrin (Talstar), clofentezine (Apollo) and tebufenpyrad (Masai) are approved for control of fruit tree red spider mite on apple but are not specifically recommended for control of apple rust mite. When applied for control of fruit tree red spider mite, they may give partial control of rust mite but should not be relied on to control damaging infestations.

Insecticides, acaricides and fungicides approved for use on apple or pear and which are recommended or likely to control apple rust mite, at least partially

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Recommended for control of	Safety to *Typhs*
bifenthrin	Brigade	pyrethroid	broad-spectrum	Red spider mite in apples and pears	harmful
clofentezine	Apollo	acaricide, ovicidal	selective	Winter eggs of fruit tree red spider mite on apple	safe
diflubezuron	Dimilin	CSI*	selective	Rust mite in apples and pears, codling, tortrix and winter moth	safe
fenpyroximate	Sequel	METI acaricide	selective	Fruit tree red spider mite in apple	safe
sulphur	various	fungicide & acaricide	selective	Scab and mildew on apples and pears. Gall mite on black-currants.	inter-mediate
tebufenpyrad	Masai	acaricide and aphicide	selective	Red spider mite in apples and pears. Damson hop aphid	us

*CSI=chitin synthesis inhibitor

METI = mitochondrial electron transport inhibitor

Choice of acaricides - Safety factors

Read and follow the label before applying any sprays

	Hazards[2]				Harvest interval (days)	Max. no. sprays or dose	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
bifenthrin	no	h,i	ed	ed	u	2	30
clofentezine	no	u	h	u	28	1	u
diflubezuron	no	u	ed	u	14	2	sm
fenpyroximate	no	h,i	ed	u	14	1	40
sulphur	no	u	u	u	0	u	u

tebufenpyrad	no	h	ed	d	7	1	18

Keys: d=dangerous, ed=extremely dangerous, h=harmful, i=irritant, t=toxic, u=unspecified or unclassified, sm= statutory minimum

*CSI=chitin synthesis inhibitor

not recommended for use with hand-held sprayers

Control in organic orchards

Emphasis should be placed on natural control by the orchard predatory mite Typhlodromus pyri. Application of foliar sprays of fatty acids (potassium soap) (Savona) or pyrethrum (various products), which are harmful to the predatory mite, should be avoided unless absolutely necessary.

- Programmes of sprays of sulphur are often applied for scab and mildew control in organic apple orchards and these suppress apple rust mite.
- Sulphur-tolerant strains of the orchard predatory mite develop eventually but the use of sulphur can lead to outbreaks of fruit tree red spider mite.

Further reading

Life cycle

Apple rust mite overwinters as a fertilised winter female (deutogyne) behind vegetative buds between the bud and the stem of the previous seasons extension growth. The overwintering females often occur in clusters of up to 100 or more in the crescent of hairs immediately behind the bud.

- The mites emerge at bud burst, walking up the leaf stalk of the outer rosette leaves and settling to feed on the leaf lamella, mainly around the base of the leaf.
- Eggs are deposited on the surface of leaves and fruit buds and a generation of males and of summer breeding females (protogynes) develops in May.
- These mites pose the greatest threat to the crop because they and their offspring feed on the receptacles of developing flowers and fruitlets the tender tissue of which is a good food source at this time, as well as on young leaves.
- Feeding on the fruitlets causes russeting damage to fruits (see 'Damage' above). Breeding continues throughout the summer, mainly on the undersides of leaves in the extension shoots, there being a number of overlapping generations of summer forms.
- Population growth is rapid particularly in hot conditions which favour the pest.
- Winter females form in the autumn and populations on leaves decline. The females enter hibernation, mainly behind buds in extension shoots.

Pest status

Apple rust mite is an important secondary pest of apple which is much more troublesome if its key natural enemy, the orchard predatory mite Typhlodromus pyri, is not present.

A similar species, the pear rust mite, Epitrimerus piri, is frequently an important pest of pear. Pear trees have smooth, hairless leaves and less prominent leaf veins than apple. They do not favour predatory mites, which are not present in significant numbers in commercial pear orchards. Outbreaks of pear rust mite are frequent on pear, almost an annual event, for this reason.

Other hosts

Both rust mite species can breed on a range of other rosaceous trees and shrubs but are usually only numerous on their main host.

Varietal susceptibility

All apple varieties are susceptible to apple rust mite, but Bramley is highly susceptible.

Distribution

Apple rust mite is very widespread and is probably present to a greater or lesser extent on practically all apple trees.

Natural enemies

The orchard predatory mite Typhlodromus pyri
Several species of predatory mite in the family Phytoseidae prey on apple rust mite, but Typhlodromus pyri is the species which occurs in selectively sprayed apple orchards and is the key natural enemy of apple rust mite because it has developed resistance to organophosphorus insecticides.

- This predatory mite is also the key natural enemy of the fruit tree red spider mite.
- If populations of the mite are conserved by avoiding the use of harmful insecticides, notably synthetic pyrethroids, apple rust mite and fruit tree red spider mite are seldom a problem.

Other predators
Rust mites are probably preyed on by several other generalist insect and mite predators such as anthocorids, mirids and the stigmaeid mite Zetzellia mali.

Monitoring

Overwintering populations
The number of apple rust mite overwintering behind buds in the previous season's extension growth should be determined in winter in orchards where a satisfactory and stable balance between the mite and the orchard predatory mite has not been established.

- A sample of at least 20 one-year extension growths should be sampled and the number of rust mites behind three buds in each shoot, one bud towards the apex, one in the middle and one at the base of the shoot, should be counted and recorded.
- This is most easily and comfortably done indoors using a microscope but the shoots need to be stored in a fridge until the counting is done.
- Alternatively, it can be done in the field, bending the shoot at the point of the bud so the bark behind the bud can be examined with a hand lens.
- The average number of rust mites overwintering per bud should be calculated.
- If the mean number of mites exceeds 10 per bud, there is a significant risk of fruit damage.

At green cluster
Examine the undersides of the outer rosette leaves, especially round the bases using a hand lens and count the number of rust mites present.

- Holding the leaf up to the light so more light shines through the leaf makes the mites more easily visible but care must be taken not to look directly at the sun as this could cause damage to eyes.
- At least 25 leaves (preferably 50) should be examined per orchard.
- An average of 5 or more mites per outer rosette leaf indicates a significant threat of damage to fruitlets.

During blossom and early fruit development (cell division)
Examine the rosette leaves as above and, importantly, also the receptacles of the flowers and the young developing fruitlets for the presence of mites.

- The mites are often found near the point where the fruit meets the calyx and this is where examination should be concentrated.
- If an average of one or more mites is found per flower or fruitlet, it is likely that some russeting damage will be caused.

In summer
More mature fruits are not susceptible to apple rust mite as their skin is less palatable. Mites occur on the undersides of leaves in extension shoots.

- The undersides of leaves should be examined to ensure they remain fresh and green.
- If any bronzing is present, leaves should be examined more closely for rust mites.
- If large populations are present and significant bronzing is being caused, treatment may be justified.

Forecasting

Forecasting methods for apple rust mite have not been developed. However, population increase can be very rapid in hot weather and bronzing damage to the undersides of leaves can intensify rapidly.

Damage

Adults and nymphs have needle-like mouthparts which they use to suck the sap from the surface cells of leaves and young developing fruitlets. Three types of damage can be distinguished.

Damage to rosette leaves caused at and shortly after bud burst
Young rosette leaves are inundated with mites emerging from behind buds which feed on the leaf tissue causing it to become dull, puckered and shrivelled.

- The outermost leaves are the worst affected, particularly around the base.

Damage to fruitlets
Mites feed on the receptacle of young developing fruitlets mainly round the calyx, swarming down the cheek when numbers are large.

- The feeding results in russeting which occurs in an irregular ring round the calyx and on the cheek of the fruit.
- The damage can be very severe if populations are high.
- The damage can be confused with 'frost eye' a ring of severe russeting round the calyx caused by frosts during or shortly after blossom. However, frost eye occurs as a clearly defined ring round the calyx.

Damage to leaves in extension shoots
Mites feed on the undersides of leaves, mainly in the younger leaves of extension shoots which are fresh and green.

- The undersides of leaves become brown (bronzed).
- As populations increase and the older leaves are less palatable to mites, so the infestation tends to move up the shoots with the growth.

Chemical control

Chemicals that are used for control of mites on apple and pear are not systemic. Higher volume spray applications to give good cover are needed to get the best results.

- Only diflubenzuron (Dimilin) is specifically recommended for control of apple rust mite. Though selective, it is only partially effective and is unlikely to control severe infestations adequately.
- A programme of sprays of sulphur (various products) at reduced rates (3-5 kg a.i. / ha), applied to control mildew on apple, will suppress rust mite and fruit tree red spider mite.
- However, multiple sprays of sulphur are likely to be harmful to the orchard predatory mite, so such an approach is not ideal.
- Some apple varieties are sulphur shy (consult the label for details) but are often safe at low rates.
- Bifenthrin (Talstar), clofentezine (Apollo), fenpyroximate (Sequel) and tebufenpyrad (Masai) are approved for control of fruit tree red spider mite on apple and are not specifically recommended for control of apple rust mite.
- When applied for control of fruit tree red spider mite, they may give partial control of rust mite but should not be relied on to control damaging infestations.

Biological control

Establishment of the orchard predatory mite, Typhlodromus pyri, is crucial. Unless the predator is established, regular outbreaks of apple rust mite and fruit tree red spider mite

are inevitable and these can be very damaging and difficult and costly to control.

- Once the predator is established and the biological equilibrium between the predatory mite and the pest mite has stabilised, rust mite and fruit tree red spider mite seldom cause problems, providing the equilibrium is not disturbed by the use of pesticides harmful to the predatory mite.
- The predatory mite will establish naturally in apple orchards but this can be a slow process.
- Pest mite infestations are often present and can develop rapidly on newly planted trees which do not have established populations the predatory mite (often because they have been sprayed with predator-harmful pesticides in the nursery e.g. with frequent sprays of fungicides to control canker).
- Where the orchard predatory mite is absent, e.g. in newly planted orchards, it should be introduced in summer by transferring extension shoots from established orchards where the predatory mite is abundant.
- Summer prunings may be used. Ideally, at least one shoot should be placed amongst the foliage in each tree of the orchard where the predator is to be introduced.

Cultural control

Young trees from the nursery used to plant new orchards are often infested with apple rust mite and/or fruit tree red spider mite and do not have established populations of the orchard predatory mite Typhlodromus pyri.

- Damage by rust mite can occur rapidly in the first season after planting whereas the pest may be unimportant in other established orchards on the farm.
- Steps should be taken to ensure the nursery trees are not heavily infested with pest mites before they are purchased and delivered to the farm.
- In orchards, hot, dry situations favour rapid population increase of apple rust mite.
- Overall bare soil orchards should be avoided.

Biotechnological control

Biotechnological control methods have not been developed for apple rust mite.

Recognition

Adults
Minute, 0.16-0.18mm long, wedge-shaped mites, yellowish-brown in colour, with two pairs of legs, each leg terminating in a branched feather-claw. Body annulated and with a distinct dorsal shield bearing a pair of setae on the hind margin. Two forms exist – the summer form (protogyne) and the winter form (deutogyne). Morphological differences between the forms can only be distinguished with the aid of a good microscope.

Nymphs
Similar to adults but much smaller.

Eggs
Minute, oval and translucent. Only visible with a microscope.

Other pests with which the pest may be confused

Fruit tree red spider mite also causes bronzing of leaves and often occurs in association with apple rust mite because insufficient predatory mites are present to regulate pest mite populations. However, the fruit tree red spider mite has a completely different appearance to the apple rust mite.

Further reading

Easterbrook, M. A. 1996. Damage and control of eriophyid mites in apple and pear. In: Eriophyid mites, their biology, natural enemies and control.

Lindquist, E. E., Sabelsi, M. W. & Bruin, J. (Eds). World Crop Pests Volume 6, Elsevier, Amsterdam, 527-541.

Apple Sawfly (Hoplocampa testudinea (Klug))

Apple sawfly is a common and important pest of apple. It does not attack pear.

Certain desert varieties, notably Discovery and Worcester, are highly susceptible.

The life cycle is simple. Adults fly during blossom and lay their eggs singly in the side of receptacles leaving characteristic scar marks. Larvae hatch out shortly after petal fall. The larvae burrow beneath the surface of the fruitlets causing characteristic ribbon scars.

More mature larvae migrate from fruitlet to fruitlet burrowing into the core and making large holes contaminated with brown wet frass. These fruits fall from the tree but those more superficially damaged (with ribbon scars) remain on the tree until harvest.

As a minimum, levels of damage must be recorded at harvest and during grading. If damage is seen one year, then insecticide treatment should be applied the next year.

As a further aid to pest monitoring, white sticky traps can be deployed in the orchard before and during blossom to catch adults. Non-UV reflective white gives the best results.

Treatment thresholds have not been determined but, if the blossom is sparse, spraying would probably be justified if more than one or two adults are caught per trap over the blossom period. Note that insecticide treatment is normally applied shortly after petal fall. Note also that the traps themselves are not sufficiently effective to control the pest by mass trapping.

Adult apple sawfly

Damaged fruitlets

Chemical control

- A spray of chlorpyrifos (Dursban, Spannit) or thiacloprid (Calypso) should be applied at or shortly after petal fall. Note: Chlorpyrifos is dangerous to bees.
- Thiacloprid (Calypso) is recommended for aphid control but experience has shown that it will also give good incidental control of apple sawfly.
- A spray of diflubenzuron (Dimilin) shortly before blossom or at petal fall, though no longer specifically

recommended by the manufacturer for sawfly control, will give partial control of apple sawfly.

- Synthetic pyrethoid insecticides such as cypermethrin or deltamethrin may also give some control of apple sawfly but are not recommended because they are harmful to predatory mites and many other natural enemies.

Characteristic ribbon scars left by larvae tunneling just beneath the surface of the skin

Insecticides and fungicides approved for use on apple which are recommended by the manufacturer or which are likely to be effective or partially effective for control of apple sawfly on apple

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of -	Safety to *Typhs*
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars, sawfly, capsids etc.	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids, capsids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
diflubenzuron	Dimilin	chitin synthesis inhibitor (CSI)	selective	Caterpillars, codling moth, earwigs, rust mite on apple and pear. (Also gives partial control of apple sawfly)	safe
thiacloprid	Calypso†	chloro-nicotinyl	Broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids and sawfly, though not caterpillars or woolly aphid)	safe

Choice of insecticides - Safety factors
Read and follow label before applying any sprays

	Hazards				**Harvest interval (days)**	**Max. no. sprays**	**Buffer zone Width (m)**
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18

deltamethrin	no	h, i	ed	d	0	u	18
diflubenzuron	no	u	ed	u	14	2	sm
thiacloprid†	no	h, i	h	h	14	2	30

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, c=closed cab required for air assisted sprayers, t=toxic, u=uncategorised/unclassified/unspecified

† not approved for use on pear

Control in organic orchards

Sawfly can be a very damaging pest in organic orchards. It is unfortunate that the disease resistant varieties Discovery and Worcester Pearmain favoured for organic apple production are very highly susceptible to sawfly.

- Priority should be given to cultural and biological control methods and fostering the parasitoids Lathrolestes ensator and Aptesis nigrocincta.
- In other countries where its use is permitted or approved, organic growers use extract of the plant Quassia amara to control apple sawfly.
- Sprays are applied at petal fall and the treatment is moderately effective.

Further reading

Life cycle

- Adults emerge on sunny days around the blossomtime of apple.
- After mating, eggs are laid throughout the blossomperiod singly in the side of the receptacle of apple flowers.
- The eggs hatch in 1-2 weeks, longer in cold weather.
- The young larva burrows into the receptacle, often just beneath the skin causing characteristic ribbon scars.
- When larvae are semi-mature, they often move to another fruitlet (often within the same truss) boring into the ovary and feeding on the pips.
- When larvae are fully fed in late June or early July, they enter the soil to form a cocoon at depths down to 25 cm.
- The larvae overwinter in cocoons before pupating 3-4 weeks before emergence the following spring.

Pest status

Important pest of apple. Does not attack pear. A similar species, the pear sawfly (Hoplocampa brevis (Klug)) attacks pear, but is local and uncommon in the UK.

Other hosts

Apple sawfly is an obligate parasite of apple and related Malus species. It has no other hosts.

Varietal susceptibility

Some desert varieties are highly susceptible notably Charles Ross, Discovery, Ellison's Orange, James Grieve and Worcester Pearmain. Culinary apples, with the exception of Early Victoria and Edward VII, are of lower susceptibility to attack.

Distribution

Widespread and common wherever apples are grown.

Damage

- The egg-laying slit in the side of the flower soon turns brown and this is readily visible as an early sign of infestation.
- Young larvae tunnel just beneath the surface of the skin of developing fruitlets leaving characteristic ribbon scars.
- Larvae bite large cavities inside fruitlets, consuming the flesh and the seeds and producing masses of wet, brown-black frass which is exuded through a large hole in the side of the fruitlet.

- Fruitlets with ribbon scars may remain on the tree until harvest but those with more severe damage fall from the tree.
- Losses can be severe, particularly when the amount of blossom or crop set is light.

Recognition

Adult
5.0-5.5 mm long. Body mainly orange with thorax and abdomen black above. Head with a conspicuous black central patch. Wings clear with brown veins.

Egg
0.8 mm long and slightly curved; white and translucent. Inserted in the receptacle of flowers and young fruitlets. Egg insertion scars are clearly visible on side of receptacle.

Larva
Up to 11 mm. Head black (early instars) to yellowish, body whitish, tapering with 7 pairs of prolegs. Produce a characteristic defensive odour.

Pupa
In soil-coloured, parchment-like cocoons in the soil.

Other pests with which apple sawfly may be confused

Codling moth
Codling moth larvae are also found commonly feeding in cavities in the centre of apple fruits.

- However, codling moth larvae tend to occur later in the season (apple sawfly larvae have vacated fruitlets to pupate in the soil by late June or early July) and codling moth larvae tend to produce dry frass at the entrance hole in the fruit surface.
- Codling moth larvae have 5 pairs of prolegs and their abdomens do not taper to the apex.
- Sawfly larvae have 7 pairs of prolegs and their abdomens taper towards their apex.

Monitoring

Adults
White, non-UV reflective sticky traps are attractive to apple sawfly adults and can be used to monitor populations in orchards.

- Place the traps in orchards at the late green cluster to pink bud growth stage of Cox.
- Examine the traps at least weekly throughout the blossom period and count the number of sawfly adults caught.
- No economic thresholds have been determined and, in any case, these will depend on many factors including the size, design and density of traps being used.
- However, on susceptible varieties, a catch of even one or two adults per trap per week can indicate that significant losses could occur if the crop set is light.
- If adult sawflies are caught, an assessment of the number of egg insertion scars should be made in the latter part of bloom to determine whether or not a post-blossom insecticide spray for control of sawfly is needed.

Egg insertion scars

Examine 100 trusses (5 from each of 20 trees) for egg insertion scars on the side of the receptacle.

- Treatment is likely to be justified if 11 or more scars are found.

Infestation and damage at and shortly after petal fall
Inspect the young developing fruitlets for signs of infestation or damage, such as ribbon scars.

- If infestation is caught early enough, the worst effects of damage can be avoided by prompt application of an insecticide spray.

Damage during the growing season, at harvest or during grading
If significant damage to fruits is seen one season, treatment the next season to avoid damage intensifying is justified.

Forecasting

The start of the flight of apple sawfly adults can be predicted using a temperature sum of 134 day-degrees above a threshold of 4 degrees C starting from 1 April.

- Soil temperatures at a depth of 5 cm must be used.
- Air temperatures are unreliable, though they can be used to predict the appropriate timing for trap installation for which the recommended temperature sum is 157 degree days above a threshold of 4 degrees C from 15 March.

Chemical control

Chemical control should be applied where a significant risk of infestation has been determined by monitoring and not as a routine.

- The main means of control is to apply an approved insecticide at or shortly after (within 10 days of) petal fall to coincide with the start of egg hatch.
- For chemical control, a spray of chlorpyrifos (Dursban, Spannit) or thiacloprid (Calypso) should be applied at or shortly after petal fall. Chlorpyrifos is dangerous to bees.
- Thiacloprid (Calypso) is recommended for aphid control but experience has shown that it will also give good incidental control of apple sawfly.
- A spray of diflubenzuron (Dimilin) shortly before blossom or at petal fall, though no longer, specifically recommended by the manufacturer for sawfly control will give partial control of apple sawfly.
- Synthetic pyrethoid insecticides such as cypermethrin or deltamethrin may also give some control of apple sawfly but are not recommended because they are harmful to predatory mites and many other natural enemies.

Insecticide resistance

Resistance of apple sawfly to insecticides is not known to occur. However, repeated use of insecticides from the same group or with the same mode of action should be avoided.

Cultural and biological control

Hygiene
Infested fruitlets, or whole trusses, which show signs of damage, can be removed from the tree when seen during larval development. However, this is very labour intensive and unlikely to be economic.

Ground herbage
Circumstantial evidence suggests that some sites are prone to the pest, possibly due to soil type or possibly the absence of a ground cover of herbage under the tree.

Natural enemies

Parasitic wasps
The ichneumonid parasitic wasp Lathrolestes ensator is an important natural enemy of apple sawfly. The parasite often regulates the pest on unsprayed garden trees where almost cyclical flare-ups of the sawfly are controlled by attacks of the parasite in subsequent years.

- The parasite only attacks late first and second instar sawfly larvae.
- The comma-shaped, black eggs of the parasite can be seen through the skin of the sawfly larva. However, the parasite egg does not hatch until after the sawfly larva has entered the soil to form a cocoon.
- Feeding and development of the sawfly larva continues normally until that time.
- The parasite has only a narrow window of opportunity to parasitise its host and unfavourable weather conditions at this time greatly limit its effectiveness.

Another parasitic wasp, Aptesis nigrocincta, is an important parasite of larvae and pupae in the soil.

Ground beetles
It is probable that larvae moving over the surface and into the soil are vulnerable to attack by predatory ground beetles, especially larger species. However, whether or not ground beetles are able to locate larvae in cocoons deep in the soil is not known.

Biological control

Attempts have been made to control sawfly with entomopathogenic nematodes as they travel to the soil to pupate with limited success.

Biotechnological control

White non-UV reflective sticky traps can be used to mass trap adults. The higher the density of traps, the greater the effect. However, it has been demonstrated that economic damage cannot be prevented even if very high trap densities (1 per tree) are used.

Further reading

Cross, J. V. & Jay, C.N. 1998. Effects of fungicides against apple sawfly. Report to APRC 1998, 5pp.

Cross, J. V., Solomon, M. G., et al. 1999. Biocontrol of pests of apples and pears in Northern and central Europe. 2. Parasitoids. Biocontrol Science and Technology 9, 277-314.

Graf, B., Hopli, H. U. & Hohn, H. 1996. Modelling spring emergence of apple sawfly Hoplocampa testudinea Klug. Acta Horticulturae 416, 263-271.

Miles, H. W. 1932. On the biology of the apple sawfly, Hoplocmpa testudinea Klug. Annals of Applied Biology 14, 420-431.

Olszak, R. W. & Maciesiak, A. 1996. Preliminary investigations of the control of apple sawfly with fungicides. Brighton Crop Protection Conference – Pests and Diseases 1996, 331-336

Owens, E. D. & Prokopy, R. J. 1978. Visual monitoring trap for the European apple sawfly. Journal of Economic Entomology 71(4), 576-578.

Zijp, J. P. & Blommers, L. H. M. 1997. Prediction of the flight of apple sawfly, Hoplocampa testudinea, using temperature sums. Entomologia Experimentalis et Applicata 84, 71-75.

Apple Sucker (Psylla mali (Schmidberger))

Apple sucker is generally a minor pest of modern desert and culinary apple orchards where it is controlled well by insecticide spray programmes. It is troublesome in unsprayed orchards, especially in organic orchards and on older trees.

It is an important and damaging pest in cider apple orchards.

The life cycle involves sucker eggs overwintering on bark before hatching at or shortly after bud burst when they invade the trusses.

The presence of the pest is indicated by blobs of waxy honeydew in the base of the trusses where the flower stalks join. Most damage is done by nymphs during the pre-blossom period.

They suck the sap from green tissue of blossom trusses and leaf buds causing brown discoloration of petals and blossom buds and, where damage is severe, buds may be killed. The discoloration resembles, and is sometimes mistaken for, frost injury.

Populations of apple sucker should be assessed along with other pests at the pre-blossom pest assessment. Examine trusses for signs of infestation or damage. The treatment threshold is 30% or more of trusses infested.

Apple sucker wax

Honeydew and wax secreted by apple sucker nymphs

Control

Spray with an approved insecticide before blossom.

Insecticides approved for control of apple sucker

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of -	Safety to *Typhs*

chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars, sawfly, capsids etc.	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids including woolly aphid, caterpillars, sucker, sawfly, capsids etc.	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
diflubezuron	Dimilin	CSI	selective	Caterpillars, codling moth, earwigs, rust mite on apple and pear. (Also gives partial control of apple sawfly)	safe

Choice of insecticides - Safety factors

Read and fllow the label before applying any sprays

	Hazards[2]				**Harvest interval** (days)	**Max. no. sprays**	**Buffer zone** Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
diflubezuron	no	u	d	u	14	3	sm

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, c=closed cab required for air assisted sprayers,

u=uncategorised/unclassified/unspecified, sm-= statutory minimum (= 5 m buffer zone width)

Control in organic orchards

Generally, there are no satisfactory controls for apple sucker in organic orchards. Cultural control approaches should be given priority. Though not specifically recommended for control of apple or pear sucker, it is probable that early season sprays of fatty acids (Savona) will give some control of apple sucker.

- The sprays have to be applied early at the green cluster growth stage (after the overwintered eggs have hatched in spring but before reproduction occurs is best) and in high volumes so that the aphids are thoroughly wetted by the spray.
- Application is sometimes made during gentle rain.

Further reading

Life cycle

There is one generation per year. Apple sucker overwinters in the egg stage. The eggs are straw coloured and are found on the bark mainly on the fruit spurs generally along leaf scars.

- Egg hatch begins in late March or April at bud-burst of Cox and Bramley and is complete by green cluster.
- The newly hatched nymphs are orange brown with red eyes. They invade the bursting buds and blossom trusses feeding on the green tissue.
- Drops of honeydew and conspicuous white or irridescent waxy threads are secreted by the nymphs and these are visible in infested trusses. No sooty mould is associated with the honeydew.
- After a second moult, the nymphs become bright green and develop wing buds.
- Feeding continues and after 4-6 weeks the first adults appear.
- The adults live and feed on apple throughout the summer and early autumn.
- Egg laying begins towards the end of August and continues for about one month. The adults then die.

Pest status

Apple sucker was once a serious pest of apple but nowadays it is well controlled by insecticides, except in organic orchards and in some cider orchards.

Other hosts

Apple sucker lives only on apple.

Varietal susceptibility

There are considerable differences in the susceptibility of varieties. Lord Lambourne and some cider varieties are highly susceptible.

Distribution

Widely distributed and common.

Recognition

Eggs
0.4 mm long, elongate oval and creamish yellow. Found on the bark of young branches and shoots, mainly around spurs and leaf buds (very similar to pear sucker eggs).

Nymphs
Apple green with red eyes, body flattened, broad and ovate, with conspicuous wing buds in later instars. Found mainly in flower trusses at the base where flower stalks meet in spring. Honey dew blobs and waxen threads betray their presence.

Adults
2.5-3.0 mm long, apple green to yellow. Wings transparent with green veins.

Monitoring

The presence of large numbers of overwintering eggs round the spurs will warn that an attack by apple sucker is likely.

- Levels of apple sucker should be assessed as part of the normal pre-blossom pest assessment at the green cluster growth stage (see section 'Pest and disease assessment').
- Ideally carefully inspect 4 trusses on each of 25 trees per orchard.
- Look out for the characteristic blobs of honey dew and wax at the base of the flower stalks. The suckers themselves can be rather difficult to see because they are a similar colour to the leaf.
- Treatment is justified if more than 30% of trusses are infested.

Forecasting

Forecasting methods for apple sucker have not been developed.

Chemical control

A spray of an approved insecticide should be applied if damaging infestations occur in spring.

- Chlorpyrifos (Dursban etc.) is the usual choice because it controls a wide range of other pests if applied at the green cluster growth stage.
- Although several synthetic pyrethroid insecticides are recommended for control of suckers on apple and/or pear the use of this class of insecticides should be avoided as they are harmful to the orchard predatory mite, Typhlodromus pyri, as well as a wide range of other natural enemies.

Insecticide resistance

Apple sucker has not developed resistance to insecticides. However, pear sucker has developed resistance to a wide range of insecticides including organophosphorus, carbamate, pyrethroid and insect growth regulator compounds.

Cultural control

Apple sucker is most troublesome in older orchards and on certain varieties. Avoiding these circumstances will reduce the problem.

- It is possible that reducing the nitrogen status of apple trees will lead to a reduction in apple sucker problems.
- This approach has been shown to be effective for pear sucker control. However, pear sucker feeds in the growing shoots and has several generations per year.

Natural enemies

Natural enemies, especially predatory flower bugs (anthocorids), should be fostered by avoiding the use of broad-spectrum insecticides

- Predatory bugs are the most important natural enemies of apple and pear sucker.

- Predatory flower bugs (anthocorids) are the commonest species but mirids such as Atractotomus mali are can also be important especially on young trees.
- The predatory bugs feed mainly on eggs and nymphs and can be important natural regulating factors if populations are not harmed by the use of broad-spectrum insecticides.

Biological control

Biological control approaches have not been developed for apple sucker.

Further reading

Jonnsson, N. 1983. The life history of Psylla mali Schmidberger (Hom., Psyllidae); and its relationship to the development of the apple blossom. Fauna Norvegica B, 30: 1, 3-8.

Life cycle

There is one generation per annum in the UK with a very small partial second flight of adults in the autumn and early winter.

- Adults of the first main generation fly in June and July, about the same time as codling moth.
- Eggs are laid (on average 70 per female at a rate of 20 per day) on foliage or amongst debris on the tree. Eggs kept at constant temperatures of 8, 18 or 25oC hatch after 44, 7 and 4 days respectively.
- Larvae occur from July to October. Initially, they feed on debris such as in the rolled edge of a dead leaf, in a dead flower or burrowed into shrivelled fruitlets.
- Older larvae construct a shelter of dead leaves and flowers webbed together.
- Damage to fruits occurs from late July onwards consisting initially of small single holes. As the larvae grow the damage becomes more extensive.
- When fully fed in the autumn or early winter, larvae leave their feeding sites and move to the soil or amongst debris on the ground where they form a silken cocoon in which they pupate.
- A small proportion of very early maturing larvae pupate and emerge the same year, giving rise to a small second flight in the autumn or early winter. If eggs are laid, they are unlikely to develop successfully.

Pest status

A serious, but local, pest of apple, especially Bramley. Attacks foliage and fruit.

Other hosts

Apple and beech appear to be the main hosts in the field. The pest can be abundant in beech hedges, which can act as a source of infestation for apple orchards.

- In the laboratory, the larvae will feed on the leaves of a wide range of plants including alder, beech, blackcurrant, bramble, cherry, Cotoneaster, dock, hawthorn, field maple, pear, plum, rose, sallow (Salix sp.), and strawberry.
- They can also be reared to adult on rose hips, hawthorn berries and dead leaves and flowers of apple trees.

Varietal susceptibility

It is probable that all apple varieties may be attacked but there are considerable differences in the susceptibility of different varieties:

- Varieties with fruits that are short stalked and/or which hang in clusters and where dead leaf and flower debris accumulates round the stalks tend to suffer the most damage.
- Bramley and Egremont Russet are amongst the most susceptible.
- Cox and Worcester are moderately susceptible, Golden Delicious is less susceptible.

Distribution

A native of Madeira, it was first found in Britain in 1946 initially restricted to the London area. Now widely distributed and locally common especially in beech hedges and apple orchards in some localities.

Damage

Larvae feed on the flesh of apple fruits around the stalks or where fruits are touching or where fruits are in contact with leaves or branches.

- They tie leaves and plant material together with silken webbing to make a shelter often attached to the surface of a fruit or branch.
- Large areas of skin and flesh are removed, wounds tend to weep and becoming covered by a sticky mass of black frass.
- They are usually surface feeders but sometimes penetrate more deeply into the flesh.
- Crop losses can be very high, approaching 100%.
- Larvae also feed on the bark of branches and the wounds may become infected with canker.

Other pests with which Blastobasis may be confused

Larvae of several leaf-rolling tortrix moths cause similar, though less severe damage, including larvae of the summer fruit tortrix moth, Adoxophyes orana.

- The damage caused by Blastobasis tends to be more severe and wounds tend to weep and become contaminated with black frass and there are deeper excavations into the flesh.

Recognition

Adult (resting)
9-11 mm long, forewings pale ochreous yellow each with four darker spots and scattered darker scales. Hindwings paler. Lie still when disturbed (e.g. by beating) characteristically scuttling round on its back sporadically.

Egg
Very pale green becoming orange-brown prior to hatching. Oval, 0.7 mm long and 0.4 mm wide. Eggs can be laid on the undersides of leaves and on dead leaves in the tree.

Larvae
Up to 10-13 mm long; purplish-brown and shiny, lighter underneath. With a darker head and prothoracic plate, rather plump.

Other pests with which Blastobasis may be confused
Larvae of several leaf-rolling tortrix moths cause similar, though less severe damage, including larvae of the summer fruit tortrix moth, Adoxophyes orana.

- The purplish-brown colour of Blastobasis larvae is distinctive.

Monitoring

Beating for adults
Unlike most moths, adult Blastobasis can be sampled using the beating method, as when dislodged from the vegetation they do not fly but fall onto the beating tray, where they either lie still or scuttle around on their backs.

- Beating should be used to determine the flight period.
- For each beat sample, a sharp tap should be made to a branch with a beater over a beating tray.
- No economic thresholds have been developed but presence of the moth is probably sufficient to justify the application of insecticide treatment.

Fruit damage
Inspecting fruits for damage, either whilst developing on the tree, windfalls, at harvest, or during grading (remembering that badly damaged fruit may have been discarded at harvest), indicates if the pest has been present and whether treatment is likely to be required the next season.

Pheromone traps
The sex pheromone of Blastobasis has been partially identified by East Malling Research and Natural Resources Institute. Attractive lures have not yet been developed.

Forecasting

Forecasting methods for Blastobasis have not been developed. However, limited information indicates that the first adult flight starts at approximately 130 day degrees above 10oC and the peak flight occurs at approximately 240 day degrees.

Chemical control

Blastobasis often goes unnoticed until harvest when the damage is done and it is too late to take remedial action for the current season. Insecticidal controls need to be timed to control caterpillars as they hatch from eggs.

- The flight and egg hatch of Blastobasis coincides approximately with that of the first generation of codling moth, so sprays times for codling moth that are effective against Blastobasis should control both pests.
- The best chemical control for Blastobasis is to apply 1-2 sprays of methoxyfenozide (Runner) or chlorpyrifos (Dursban etc.) to give a protective deposit of insecticide during the egg hatch period.
- It is probable that indoxacarb (Steward) is also effective.
- The insecticidal protection should be maintained continuously by spraying a suitable insecticide at 2-3 week intervals from 1 week after the start of the flight period until 2-3 weeks after the end of the flight period, remembering that the maximum number of applications of any insecticide used.
- Use of chlorpyrifos (Dursban etc.) or methoxyfenozide (Runner) for codling and tortrix moth control will give incidental control of Blastobasis, though it is wise to extend the insecticidal protection into July where there is a serious Blastobasis problem.
- Bacillus thuringiensis fenoxycarb (Insegar) and diflubenzuron (Dimilin) have little activity against Blastobasis.
- Synthetic pyrethroids are highly effective but their use should be avoided because they are harmful to the orchard predatory mite Typhlodromus pyri.

Insecticide resistance

Resistance of Blastobasis to insecticides is not known to occur but has not been investigated.

Cultural control

Cultural control options for this pest are limited. Beech hedges often harbour the pest, so removal of these if the pest is present is likely to be helpful.

- Thinning fruits so that they only occur singly will also reduce damage substantially.
- Where larvae are found on fruits during picking at harvest, they should be killed.

Natural enemies

Little is known about the natural enemies of Blastobasis. No parasitic wasps have been reared from samples of larvae collected in the field.

- It is probable that a wide range of generalist insect predators such as anthocorids, mirids, lacewing larvae, earwigs etc. feeds on eggs and young larvae.
- Numerous earwigs are often present in the vicinity of semi-mature caterpillars feeding in shelters amongst fruits and leaves.
- The shelters appear to provide good protection against them but, sometimes, vacant shelters occupied by earwigs are found giving the impression that earwigs might be important predators of Blastobasis.

Biological control

Biological control methods have not been developed. Unfortunately, sprays of Bacillus thuringiensis have only limited efficacy against the pest.

Further reading

Alford, D. V. 1980. Blastobasis decolorella (Wollaston) (Lepidoptera: Blastobasidae), a potentially serious apple pest. Plant Pathology 29, 145-146.

Easterbrook, M. A. 1985. The biology of Blastobasis decolorella (Wollaston) (Lepidoptera: Blastobasidae) a potentially serious pest of apple. Entomologist's Gazette 36, 167-172.

Easterbrook, M. A., Solomon, M. G. & Fitzgerald, J. D. 1985. Control of Blastobasis decolorella (Lepidoptera: Blastobasidae), a new pest of apple. Journal of Horticultural Science 60, 33-36.

Blastobasis (Blastobasis decolorella (Wollaston))

Blastobasis is a highly damaging, but local, pest of apple. The life The life cycle involves one main mid summer generation with a very small partial second flight of adults in the autumn and early winter. The caterpillars feed on the flesh of ripening fruit around the stalk or where two or more fruits are touching.

Apple varieties with short stalks, notably Bramley and Egremont Russet, are highly susceptible. Cox is moderately susceptible.

Look out for signs of damage at harvest. The purplish-brown caterpillars remove large areas of skin and flesh, the wounds tending to weep and are sometimes covered by a sticky mass of black frass. The caterpillars form shelters for themselves by tying leaves together with silken webbing, often to the surface of a fruit. Sometimes

caterpillars penetrate more deeply into the flesh.

Crop losses can be very high, approaching 100%. The damage is sometimes overlooked or misidentified because of failure to distinguish the damage from that caused by tortrix moth caterpillars.

If damage is seen one year, even at a low level, insecticidal treatment to prevent the pest increasing should be applied the next season.

Beech hedges sometimes harbour the pest and can act as a source of infestation. Hand thinning fruits to singles will reduce damage.

Recognition is relatively straightforward. Adult Blastobasis are 9-11 mm long at rest and have pale ochreous yellow forewings each with four darker spots and scattered darker scales. They occur in June and July, about the same time as codling moth. To monitor numbers they can be sampled using the beating method as when dislodged from the vegetation they do not fly but fall onto the beating tray, where they characteristically either lie still or scuttle around on their backs. Beating should be used to determine the flight period.

Control

- The best chemical control is to apply 1-2 sprays of methoxyfenozide (Runner) or chlorpyrifos (Dursban etc.) to give a protective deposit of insecticide during the egg hatch period.
- It is probable that indoxacarb (Steward) is also effective.
- The insecticidal protection should be maintained continuously by spraying a suitable insecticide at 2-3 week intervals from 1 week after the start of the flight period until 2-3 weeks after the end of the flight period, remembering that the maximum number of applications of any insecticide used.
- Use of chlorpyrifos (Dursban etc.) for codling and tortrix moth control will give incidental control of Blastobasis, though it is wise to extend the insecticidal protection into July where there is a serious Blastobasis problem.
- Bacillus thuringiensis and diflubenzuron (Dimilin) have little activity against Blastobasis. Synthetic pyrethroids are highly effective but their use should be avoided because they are harmful to the orchard predatory mite Typhlodromus pyri.
- The activity or otherwise of fenoxycarb (Insegar) has not been determined.

Blastobasis caterpillar

Blastobasis caterpillar damage to Bramley fruits

Shelter made by Blastobasis caterpillar attached to fruit

Deep flesh injury to Cox by Blastobasis caterpillar

Insecticides approved for control of codling, tortrix moths or caterpillars on apple and pear that are known or likely to be effective against Blastobasis caterpillars - Download table

Control in organic orchards

Blastobasis is potentially a devastating pest in organic apple orchards and could possibly make organic apple production impossible.

- If the pest starts to occur, cultural control measures, especially hand thinning of fruits to singles should be given priority.
- A programme of sprays of Bacillus thuringiensis or pyrethrum may be applied (at the same timings as

- A programme of sprays of Bacillus thuringiensis or pyrethrum may be applied (at the same timings as recommended for chlorpyrifos above but at 1-2 week intervals) but this approach is likely to be of limited efficacy.

Further reading

Codling moth (Cydia pomonella L.)

Codling moth is a key pest of apple, which attacks the fruit directly causing economic damage at low population densities. It is sometimes very damaging to pear.

The life cycle involves one complete and one partial generation per year in southern Britain, though two generations occur in hot summers.

First generation adults emerge in May to July and fly at dusk on warm evenings. Eggs are laid singly on leaves and the surface of fruits. Larvae hatch after 7 10 days, depending on temperature, and cause damage by boring into the flesh of the fruit. A characteristic entrance hole is left, partially blocked by dry frass.

This readily recognised pest should be monitored using pheromone traps, monitored weekly from petal fall until harvest. The threshold is 5 moths per trap per week for two weeks, not necessarily successive.

Adult Blastobasis

Adult codling moth

Control

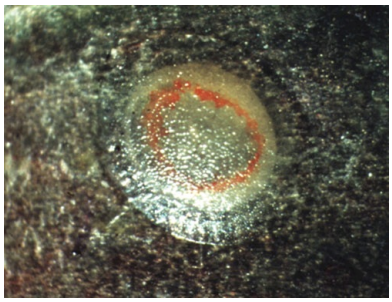
In addition to sanitation measures which help reduce the worst ravages of attack, there are three different approaches for controlling codling moth:

1. biological control with sprays of the codling moth granulovirus
2. chemical control with sprays of insecticides which are either ovicidal, larvicidal or both
3. sex pheromone mating disruption with a grid of Exosex autoconfusion dispensers.

Biological control

Now that the codling moth granulovirus (Cyd-X) is available, it should be used wherever possible, bearing in mind the following limitations:

- It only controls codling moth and not tortrix moths, Blastobasis or other pests
- A maximum of three sprays each giving 8-14 days protection is allowed per season
- Heavy attacks may result in some superficial sting injury as the young larvae hatching from eggs do not die immediately.



Codling moth egg

Chemical control

A chemical control programme should comprise a series of sprays of insecticides at 2-3 week intervals, maintaining an insecticide deposit throughout periods of risk.

- The interval between sprays should be 2 weeks if temperatures are high or if the risk is high.
- The choice of insecticides is fenoxycarb (Insegar) or diflubenzuron (Dimilin) applied at or shortly before the onset of egg laying, or chlorpyrifos (Dursban, Spannit etc), indoxacarb (Steward), methoxyfenozide (Runner) or spinosad (Tracer) at applied at the onset of egg hatch.
- Use of synthetic pyrethroid insecticides, which are very effective, should be avoided as they are harmful to predatory mites and many other important natural enemies.
- The onset of egg laying is when a threshold pheromone trap catch is exceeded.
- Egg hatch occurs 7-10 days later.
- The interval between egg laying and egg hatch can be estimated more precisely by accumulating percentage egg development amounts calculated from daily maximum and minimum air temperature.
- First egg hatch is expected when the accumulated sum reaches 100%.
- Be vigilant for second generation attacks, which occur in August in hot summers.

Codling moth larva in fruit

Sex pheromone mating disruption

The Exosex CM codling moth pheromone autoconfusion system provides another codling moth control option.

- A lattice of 25 delta dispensers per ha is set out in a grid through the orchards at the start of the codling moth flight in May, as indicated by sex pheromone trap catches.
- Each dispenser contains wax powder loaded with the codling moth sex pheromone in its base and a sex pheromone lure.
- The lure attracts males into the dispensers here they become contaminated with the pheromone-loaded powder which is attracted electrostatically to their bodies.
- Contaminated males are confused and also attract other males so preventing or delaying mating of females.
- Like other sex pheromone mating disruption systems, it only gives adequate control of low codling moth populations and should be used in combination with other codling moth control measures including granulovirus and/or insecticides.

Codling moth entrance hole in fruit ('sting' injury)

Products approved for control of codling, tortrix moths or caterpillars on apple and pear

Choice of insecticides - efficacy factors

Active ingredient	Trade names	Class[1]	Selectivity	Label rec's[2]	Safety to *Typhs*	Suggested interval between sprays (days)
chlorpyrifos	Dursban, etc.	OP	broad spectrum	c, cm, t	safe	14-21
cypermethrin	various	pyrethroid	broad spectrum	c, cm, t	harmful	14-21
codlemone	Exosex CM	sex pheromone mating disruption	highly selective	cm	safe	-
codling moth granulovirus	Cyd-X	microbial biocontrol	highly selective	cm	safe	8
deltamethrin	Decis	pyrethroid	broad spectrum	cm, t	harmful	21
diflubenzuron	Dimilin	CSI	selective	c, cm, ftt	safe	28
fenoxycarb	Insegar	JHA	selective	sft	safe	21
indoxacarb	Steward	oxadiazine	selective	c, cm, ftt, sft	u	10-14
methoxyfenozide	Runner	MAC	selective	c	safe	u
spinosad	Tracer	neural blocker	selective	C, cm, ftt,sft	safe	10

Choice of insecticides - Safety factors

Read and follow the label before applying any sprays

	Hazards[3]				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
chlorpyrifos	yes	i,h	ed	ed	14	3	18
cypermethrin	no	i,h	ed	d	0	5	18
codlemone	no	u	u	u	-	-	-
codling moth granulovirus	no	h,i	u	u	14	3	u

deltamethrin	no	i,h	ed	d	0	u	18
diflubenzuron	no	u	u	u	14	3	u
fenoxycarb	no	u	d	d	42	2	18
indoxacarb	no	h	ed	u	7	3	15
methoxyfenozide	no	u	u	u	14	3	5
spinosad	no	u	ed	u	7	4	40

Keys: [1]OP=organophosphate, CSI=chitin synthesis inhibitor, JHA=juvenile hormone analogue MAC= moulting accelerating compound

[2]c=caterpillars, cm=codling moth, ftt=fruit tree tortrix, sft=summer fruit tortrix, t=tortrix

[3]d=dangerous, ed=extremely dangerous, h=harmful, ir=irritant, t=toxic u=no hazard specified

Control in organic orchards

Organic growers should use both codling moth granulovirus (Cyd-X) sprays (one or two sprays against each generation, not exceeding the maximum of 3 sprays) and in combination with season-long maintenance of Exosex pheromone autoconfusion system.

- Note that Bacillus thuringiensis has little effect on codling moth.
- Cultural control remains an important additional measure.

Further reading

Life cycle

Codling moth has one complete and one partial generation per year in southern Britain, though two generations occur in hot summers.

- Adults occur from mid-May to early September but are most numerous from mid June to mid July.
- Second generation adults occur in August-early September. They fly at and after dusk on warm evenings when the temperature >15 degrees C.
- Eggs are laid singly on foliage of fruitlets. They hatch 10-14 days depending on temperature. Egg development takes 85.5 +/- 8.9 degree days above a threshold of 10 degrees C.
- Larvae invade fruit (see 'Damage') and pass through 5 instars becoming fully grown in about 4 weeks.
- Larvae vacate fruit and spin cocoons under loose bark, in cracks in the trunk or supporting stake etc. or in dead plant material in the ground cover.
- Most larvae over-winter in their cocoon and pupate in Spring, but those that spin by the end of July may pupate and produce a second, usually partial, generation of adults in August and early September.
- Late-developing larvae still inside the fruits after harvest often form their cocoons in cracks in apple bins or other places in fruit stores and pack-houses.

Pest status

Key pest of apple, less frequently pear though attacks on pear can be very damaging. Attacks fruit directly, so economically important at low population densities.

Other hosts

Walnuts, Malus sp, quince.

Varietal susceptibility

Host plant resistance is not known to occur in apple cultivars though some Malus sp. with high malic acid content may be resistant.

- Early harvested varieties may escape attack from second generation larvae.
- Pear varieties with stone cells round calyx (e.g. Bartlet) are of low susceptibility as larvae are unable to penetrate flesh.

Distribution

Widespread and common. World-wide distribution wherever apples are grown except possibly Japan and parts of S.America.

Damage

Newly hatched larva (one per fruit) burrow through skin into the flesh and through to the core.

- The entry point is often at the calyx (smaller fruits) or on the cheek (larger fruits).
- The entry hole is prominent and red-ringed, characteristically blocked by dry frass.
- Cut open fruit to reveal cavity, frass and sometimes the larva.

- Damaged fruits often fall prematurely and are found on the ground under the tree.

Other pests with which codling moth may be confused

Fruitlet mining tortrix
Larval attacks by the fruitlet mining tortrix occur shortly after blossom.

Blastobasis decolorella
Caterpillars sometimes burrow into fruits from July-September, but damage is usually associated with extensive surface damage.

Recognition

Adult (resting)
Length 8-11 mm, ash grey with characteristic coppery blotch at wing tip.

Egg
1.3 x 1.0 mm, flat, oval and translucent. Found on foliage or fruits, mainly the latter when fruits are more mature.

Larva
Typical tortrix form with 5 pairs of prolegs, none on the first two abdominal segments. Up to 20 mm long, pale pinkish white (younger instars whitish). Head and pro-thoracic plate brown. Usually found inside fruit.

Pupa
Inside thin cocoon. 8-10 mm long, brown. Often found in bark and other crevices.

Other pests with which codling moth may be confused

Apple sawfly
Sawfly larvae are also found in fruit but only up to mid-June. Sawfly larvae taper to tip of abdomen and have 7 or more pairs of pro-legs, though the first abdominal segment is without prolegs.

Fruitlet mining tortrix
Larval attacks by the fruitlet mining tortrix occur shortly after blossom.

Blastobasis decolorella
Caterpillars sometimes burrow into fruits from July-September, but damage is usually associated with extensive surface damage. Blastobasis caterpillars are dark purple-brown in colour.

Monitoring

Pheromone traps
The flight activity of male moths should be monitored using sex pheromone traps. The delta trap design is used widely.

- Traps should be set out in orchards shortly after blossom (where the fruitlet mining tortrix is a problem locally, codling moth traps, which also attract males of the mining tortrix, should be set out before blossom).
- Ideally, each orchard should be individually monitored with at least one trap.
- The traps should be hung from the branch of the tree at canopy height in the centre of the orchard and oriented to allow air flow through the trap by the prevailing wind.
- The number of moths caught in each trap should be recorded weekly and the dead moths removed.
- Lures should be changed every 4-6 weeks as recommended by the manufacturer. Sticky bases should be changed when their effectiveness declines significantly.
- The usual threshold for treatment is 5 moths per trap for two weeks, not necessarily successive.
- If a large catch (>20 moths) accrues in one week, it should be regarded as exceeding the threshold.

Fruit damage
Inspecting fruits for damage either whilst developing on the tree or at harvest or grading, may indicate if populations are high and damage is likely from the next generation.

- Dropped fruits on the ground under the tree may also be examined in summer.
- Damage exceeding 1% of fruits infested is cause for concern.

Trunk banding
The cultural control measure of applying trunk bands may be used for monitoring.

- Set a band on a sample of trees and count the number of cocooning larvae and pupae.

Forecasting

The rate of development of each of the life stages of codling moth is highly dependant on temperature and development is only completed when a known heat sum has accumulated. Heat sums are calculated each day from the daily maximum and minimum temperature.

- A heat sum method can be used to calculate the duration of egg development to estimate the time from the onset of egg laying to the onset of egg hatch.
- The PESTMAN computer based forecasting model uses heat sums to give predictions of the timing of the flight periods of codling and tortrix moths based on daily maximum and minimum air temperatures recorded from 1 January.
- The model is best used in conjunction with pheromone traps which can be used to 'biofix' the timing of the moth flight, improving the accuracy of the forecasts.
- The model is particularly useful for predicting the timing of the onset of egg hatch and the occurrence of a second generation.

Biological control

Codling moth granulovirus
Now that the codling moth granulovirus (Cyd-X) is available and approved for use in the UK, it should be used wherever possible, bearing in mind the following limitations:

- It only controls codling moth and not tortrix moths, Blastobasis or other pests
- A maximum of three sprays each giving 8-14 days protection is allowed per season
- Heavy attacks may result in some superficial sting injury as the young larvae hatching from eggs do not die immediately.

Key aspects of the virus are:

- The virus is highly selective and virulent. In orchards, only codling moth can be infected. A single virus particle is sufficient to kill a first instar codling moth larva.

The virus is totally safe to man, plants and the environment, though the formulants included in the product may be harmful. No 'pesticide residues' occur on fruits at harvest.

- The virus has to be ingested by the newly hatched larva when feeding on the skin of the apple before it penetrates the flesh. The larva continues feeding for a few days before the virus acts. This results in small, shallow, larval feeding holes in the surface of the fruit, known as 'sting' injury. Although sting injury is superficial, it can result in downgrading of fruit to a lower quality class. **This injury is the main disadvantage of the virus.**
- The virus is sensitive to UV light and high temperatures which limit its persistence. In hot/sunny weather, protection lasts about 8 days. In cooler, cloudy weather protection lasts up to 14 days.
- A programme of sprays of the virus at 8-14 day intervals, starting from the onset of egg hatch (see 'Chemical control') and continuing until hatch is complete is usually required, remembering that there is a maximum of three sprays per annum.
- The virus is compatible with most fungicides. Higher volume sprays are considered to be more effective. A feeding stimulant, such as molasses, sugar or milk powder may be added to the spray solution to increase the amount and rate of larval feeding and hence improve the efficacy of the treatment.
- First generation larvae that overwinter can carry over sub-lethal infections of the virus to the following season
- User of the granulovirus against the second generation of codling moth in late July or August as opposed to using insecticides will reduce the likelihood of pesticide residues occurring on fruits at harvest. However, in the UK, the second generation larvae do not usually complete their development, so mature larvae and pupae carrying sub-lethal infection will not be carried over to the next season.

Bacteria
Sprays of Bacillus thuringiensis (Bt) at the egg-hatch period may give a limited degree of control of codling moth. However, the newly hatched larvae only feed for a short time before boring into the fruit and do not usually ingest an adequate dose.

Nematodes
A spray of the entomopathogenic nematode Steinernema carpocapse applied to the trunk and main branches in September or early October can give over 80% control of cocooning larvae.

- However, it is vitally important that the weather conditions are suitable at the time of application and after application.
- The air temperature must be above 14 °C and the surface of bark must remain wet for at least 24 hours during and after application..
- The spray should be applied at high volume. Nematodes are exempt from pesticide registration requirements, but they must be a native strain or a strain licensed for release in the UK.

Parasitic wasps
Egg parasites (Trichogramma sp.) are available from biological suppliers and can be introduced but efficacy is poor even if huge numbers are introduced making the method uneconomic.

Chemical control

Although codling moth resistance to insecticides resistance is widespread in other countries it has probably not yet developed in the UK. Chemical control thus remains the principle means of control in the UK because as it is both cheap and effective.

Control with larvicides including chlorpyrifos, pyrethroids, indoxacarb (Steward) or spinosad(Tracer)
Several insecticides including the OP chlorpyrifos (Dursban etc.), the pyrethroids bifenthrin, cypermethrin, deltamethrin, indoxacarb (Steward) and spinosad (Tracer) are approved for control of codling moth or other caterpillars on apple in the UK and act by killing larvae.

- For codling moth control, the newly hatched larvae must be exposed to a lethal dose before they burrow into the fruit, either by ingestion or contact action.
- The use of synthetic pyrethroids should be avoided as they are harmful to predatory mites and other natural enemies.
- Note also that chlorpyrifos and pyrethroids are broad-spectrum compounds which are harmful or toxic to humans and the environment.
- The first spray for each generation is timed to coincide with the onset of egg hatch. This time is determined from pheromone trap catches.
- The first above-threshold catch (>5 moths for two weeks) indicates the date when egg laying commences.
- Eggs take on average 7-10 days to hatch, but the length of time varies greatly with temperature.
- The first spray is applied 7-10 days later (use the shorter interval in warm weather) to coincide with the onset of egg hatch.
- The duration of egg development can be calculated more accurately if desired from daily maximum and minimum air temperatures.
- Cumulate the percentage egg development that occurs each day starting from the first day that an above threshold pheromone trap catch is obtained.
- The day can usually be determined within a day or two by looking at daily temperatures and identifying particularly warm days in the week preceding the weekly record of the catch.
- Moth flight generally occurs when dusk temperatures are >15oC. However, accurate calculation of the date of hatching is not very important as most insecticides are fairly persistent and give control for 2-3 weeks providing they are applied before significant egg hatch has started.
- The first spray against the first generation neonate caterpillars will generally be 5 6 weeks after petal fall in the second half of June, but may be earlier if the weather is warm.
- An effective residue of insecticide needs to be maintained on the leaf and fruit surface throughout the duration of the egg hatch period.
- A single spray is normally sufficient where infestations are light but two or more sprays may be necessary for more severe infestations as indicated by continuing high pheromone trap catches.
- The interval between sprays depends on the effective persistence of the product used. In hot summers there may be a second generation in August which can be very damaging.
- This may justify a further spray but care must be taken to avoid infringing harvest intervals, especially on early varieties.

Control with chitin synthesis inhibitor insecticide diflubenzuron (Dimilin)
Chitin synthesis inhibitor insecticides inhibit the development of chitin, which is the protein from which the insect's skin (exoskeleton) is formed.

Diflubenzuron (Dimilin) is a chitin synthesis inhibitor with ovicidal and larvicidal activity against codling moth.

- It is a selective insecticide which is comparatively safe to humans and the environment and very effective against codling moth.
- However, it can have adverse effects on earwig populations thereby causing outbreaks of other pests for which earwigs are important natural enemies, notably woolly aphid.
- It is reputed to be particularly harmful to earwigs if sprayed at night as earwigs are nocturnal.
- The first spray of diflubenzuron (Dimilin) for codling moth control is applied at the onset of egg-laying i.e. as soon as the first threshold catch occurs.
- It is important not to delay spraying for 7-10 days until egg hatch as a deposit of the insecticide has to be present before or shortly after the egg is laid for best results.
- Further sprays may be necessary if the egg laying period is prolonged or if there is a second generation.

- The main disadvantage of diflubenzuron (Dimilin) as a codling moth control agent is that it is not effective against the summer fruit tortrix moth, another important pest which may require chemical control at this time.

Control with the juvenile hormone analogue insecticide fenoxycarb (Insegar)
Juvenile hormone is an insect hormone which controls morphogenesis (from larva to pupa) and egg development in insects. Juvenile hormone analogues such as fenoxycarb (Insegar) interfere with these natural processes, causing mortality.

- Although fenoxycarb (Insegar) is not specifically recommended by the manufacturer for control of codling moth on apple or pear, it is recommended for control of the summer fruit tortrix moth and will give incidental control of codling moth where it is used.
- It is a juvenile hormone analogue and only acts against codling moth eggs, not against larvae which are inaccessible to the insecticide at the susceptible late-larval stages when they are inside fruits. It has 2-3 weeks effective residual activity on leaves and fruits.

Control with the moulting accelerating insecticide methoxyfenozide (Runner)
Methoxyfenozide (Runner) is a moulting acceleration insecticide and is effective mainly when ingested on the egg to L2 larval stages.

- It has minimal contact action.
- The active ingredient mimics the action of the moulting hormone (ecdysone) of moth larvae (L1 – L2 stages), and differs from other insect growth regulators such as the chitin biosynthesis inhibitor diflubenzuron (Dimilin) or juvenile hormone analogue fenoxycarb (Insegar).
- Upon ingestion, caterpillars undergo an incomplete and developmentally lethal premature moult.
- After ingestion, larvae cease feeding within 4-8 hours. They die because they are unable to feed and complete the moulting process.
- The first spray of methoxyfenozide (Runner) is best applied a few days before the onset of egg hatch of codling moth.
- It has 2-3 weeks effective residual activity and is very effective against other caterpillar pests of apple including tortrix moths and Blastobasis.
- Note that a maximum of 3 sprays is permitted per season

Insecticide resistance

Codling moth populations are widely resistant to conventional and insect growth regulator insecticides in southern and central Europe. The resistance has forced growers in those regions to adopt alternative control strategies, mainly using pheromone mating disruption and/or codling moth granulovirus. Resistance has not been shown to occur in the UK.

Avoiding the development of insecticide resistance

Although codling moth has probably not yet developed resistance to insecticides in the UK, resistance is widespread in other countries, especially where the moth has multiple generations.

- There is a risk that resistant moths will be imported on fruit or nursery trees from these countries but the probability of this happening is low.
- The chance of the resistance developing in the UK can be greatly reduced by alternating the group of insecticide used for control and not relying on insecticides from one group continually.

Sex pheromone control

There are three basic methods by which a pest's sex pheromone can be exploited for control:

- Mating disruption where the pheromone is used alone to interfere with the normal attraction of males to females by providing false trails and/or sensory overload
- Mass trapping where the sex pheromone is used to attract males to a trap where they are captured and killed physically
- Attract and kill where the sex pheromone attracts males to a device or place where they come into contact with an insecticide

The Exosex CM codling moth pheromone autoconfusion system
This is a special mating disruption system and is the only sex pheromone control system currently approved and available for control of codling moth in the UK. It provides another codling moth control option.

- A lattice of 25 delta dispensers per ha is set out in a grid through the orchards at the start of the codling moth flight in May, as indicated by sex pheromone trap catches.
- Each dispenser contains wax powder loaded with the codling moth sex pheromone in its base and a sex pheromone lure.
- The lure attracts males into the dispensers here they become contaminated with the pheromone loaded powder which is attracted electrostatically to their bodies.
- Contaminated males are confused and also attract other males so preventing or delaying mating of females.
- Like other sex pheromone mating disruption systems, it only gives adequate control of low codling moth populations and should be used in combination with other codling moth control measures including granulovirus and or insecticides.

Other pheromone mating disruption systems
Conventional mating disruption systems utilise a lattice of pheromone dispensers, typically 500-1000 per ha containing up to 150 g of pheromone per ha, spread through the orchard just as adult moths start to emerge.

- Male moths are confused by the synthetic pheromone and are unable to find females.
- Although commercial products are available in many other European countries and are used on a large scale, there is currently no approved product for use in the UK.
- Pheromone mating disruption is most successful if used on a large scale and when populations are low initially.
- It is generally more expensive than chemical control or biocontrol using the codling moth granulovirus and has a high labour requirement for application.
- For this reason it is only used in areas where codling moth has developed resistance to insecticide.

Pheromone attract and kill:
The sex pheromone is incorporated into a material together with an insecticide (usually a synthetic pyrethroid).

- Blobs of the material are extruded onto the trunk and branches of trees throughout the orchard (typically 1-2 blobs per tree) at the start of moth flight, as indicated by pheromone traps.
- The males attempt to mate with the blobs, picking up a dose of insecticide in the process.
- The technique is effective and uses a fraction of the amount of insecticide used in an insecticide spray treatment.
- However, no product is approved for use in the UK currently.

Other non-chemical control methods

Sterile insect release

In Canada, codling moths are mass-reared, sterilised and released in an area-wide codling moth control programme.

- The sterile males mate with the wild females which lay infertile eggs. Insecticide sprays are not then needed for control.
- The approach is effective, though costly and cannot be used by individual growers.

Cultural control

Many cultural control approaches require high labour inputs and are only likely to be appropriate where other effective control measures are not available.

Old trees

- Old trees with rough, creviced bark provide numerous cocooning sites for larvae.
- Young trees with smooth bark may be less severely attacked.
- In this situation, many codling moth larvae spin cocoons and hibernate in dead plant material in the ground cover.

Spatial isolation

- Commercial orchards should be isolated as far as possible from unsprayed orchards and garden trees which are often a source of infestation.

Hygiene

- Fallen, infested fruits may be removed promptly and destroyed before larvae can exit and move to cocooning sites.
- Developing fruits may be inspected in July and infested fruits removed and destroyed.
- Bulk bins may be disinfected after use.
- Discarded fruit from the pack-house should not be allowed to act as a source of infestation.

Trunk banding

- A band of sacking, corrugated cardboard or another suitable material may be secured round the trunk of each tree in June before larvae exit the fruitlets.
- The band will provide a cocooning site for larvae.
- The band should be temporarily removed in August and cocooning larvae destroyed.
- This process should be repeated in winter.

Natural enemies

Codling moth has many natural enemies but these are not sufficiently effective to regulate populations below damaging levels.

Insectivorous birds
Tits, especially, pick larvae and pupae in cocoons from bark crevices, but do not forage specifically for the pest unless population densities are very high and for this reason are of only limited value.

Egg parasites
The egg parasite Trichogramma can be introduced (4 releases of 2.5 m per ha have been shown to reduce damage by 50-80%) but such introductions are not cost effective. Ascogaster quadridentatus is a common, naturally-occurring parasite which lays a single egg in the codling moth egg but develops within the host larva.

Larval/pupal parasites
Many species of parasitic wasp attack codling moth larvae and/or pupae.

Predatory insects
Earwigs and predatory mirid and anthocorid bugs are known to feed on Codling moth eggs and young larvae.

Entomopathogenic fungi
Many species of entomopathogenic fungi, notably Beauveria bassiana, cause significant mortality in overwintered larvae and pupae.

Entomopathogenic nematodes
Neoaplectana carpocapsae are significant natural enemies of overwintering larvae/pupae on tree trunks, especially close to the soil surface.

Virus diseases
Codling moth granulovirus is usually associated with biocontrol applications though the virus can overwinter from one year to the next at a low level.

Further reading

Van der Geest, L. P. S. & Evenhuis, H. H. (Eds). 1991. Tortricid Pests, Their Biology, Natural Enemies and Control. World Crop Pests, Vol. 5. Elsevier, Amsterdam.

Common green capsid (Lygocoris pabulinus (Linnaeus))

Common green capsid is a widespread and abundant readily recognised insect and, in some years, is an important pest of apple and pear.

The life cycle involves overwintering as eggs inserted by adults into the tender shoots of woody plants in the autumn. Rootstock sucker growths, especially at the edges of orchards where the pest is usually most abundant, often harbour the pest and should be removed in winter.

Apple and pear orchards should be inspected for the pest or signs of damage at the late blossom stage of apple. At least 25 trees per orchard should be examined for signs of damage.

Adult common green capsid

Control

A spray of an approved insecticide should be applied promptly at petal fall if damaging infestations are detected.

- Chlorpyrifos (various products) is known to be highly effective and will also control several other pests if applied at this time.
- Thiacloprid (Calypso) applied for control of rosy apple aphid at this stage will also control capsids as

- Thiacloprid (Calypso) applied for control of rosy apple aphid at this stage will also control capsids as well as other petal fall pests including apple sawfly.
- Several other novel insecticides recently approved for control of aphids on apple and/or pear in the UK may have useful activity against capsid bugs including acetamiprid (Gazelle), flonicamid (Teppeki, Mainman) and thiamethoxam (Centric).

Capsid damage

Insecticides approved for use on apple or pear that are recommended or likely to be effective for control of capsids on apple

Capsid damage to red Charles Ross fruit

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class[1]	Selectivity	Approved for control of	Safety to *Typhs*
acetamiprid	Gazelle	neonicotinoid	partially selective	Aphids	safe
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids, caterpillars, sawfly etc.	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
flonicamid	Mainman, Teppeki	feeding blocker aphicide	selective	Aphids	safe
thiacloprid	Calypso†	chloro-nicotinyl	broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids and sawfly, though not caterpillars or woolly aphid)	safe
thiamethoxam	Centric	neonicotinoid	broad-spectrum	Aphids and pear sucker	safe
nicotine*	various	alkaloid	broad spectrum	Aphids including	harmful

				woolly aphid, caterpillars, sawflies	
pyrethrum	Pyrethum 5 EC	pyrethrum plant extract	broad-spectrum	Aphids, caterpillars, spider mites, thrips	harmful

Choice of insecticides - Safety factors

Read and fllow label before applying any sprays

	Hazards[3]				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
acetamiprid	no	u	h	u	14	2	20
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
flonicamid	no	u	h	u	21	3	sm
thiacloprid	no	h, i	h	h	14	2	30
thiamethoxam	no	h	h	d	14	2	sm
nicotine*	no	t, h	d	h	2	u	u
pyrethrum	no	h,i	d	h	1	us	us

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, t=toxic, c=closed cab required for air assisted sprayers, u=uncategorised/unclassified/unspecified

† not approved for use on pear

*approval for use and storage of all products containing nicotine is allowed only until 8 June 2010

Control in organic orchards

Greater emphasis should be placed on cultural and biological control methods in organic orchards.

- Pyrethrum is the only chemical control for the pest in organic orchards.
- It is of short persistence and probably of limited activity.
- One or more sprays should be directed against the pest shortly before and/or shortly after blossom.
- Pyrethrum is harmful to the orchard predatory mite Typholdromus pyri, so use in organic orchards should be avoided if possible.
- Neem extract does have an effect and is used in other European countries for control in organic orchards.

Further reading

Life cycle

Common green capsid overwinters as eggs inserted into the bark of young, tender shoots of woody hosts, including apple, pear, currant and gooseberry.

- The eggs hatch in April over an extended period of several weeks between the pink bud growth stage and the end of blossom of apple.
- The nymphs are active and feed in the growing points of shoots and on young developing fruits until early May when they migrate to herbaceous hosts such as potato, strawberry and many weeds.
- Here they continue their development until the adult stage.
- Adults are very active and frequently fly in sunshine.
- In late June and July, eggs are laid in the stems of summer herbaceous hosts such as potato, bindweed, dandelion, nettle, dock and many other weeds.
- A second generation develops on these hosts reaching adulthood by the autumn.
- A return migration to woody winter hosts occurs where eggs are eventually laid, especially in young, tender shoots.

Pest status

It is frequently a damaging pest of apples and sometimes pears. More serious outbreaks seem to occur in certain years, with the pest being much less important in others.

Other hosts

All fruit crops can be attacked as well as certain arable crops, notably potatoes.

Varietal susceptibility

All apple and pear varieties are susceptible.

Distribution

Widespread and abundant.

Damage

- Adults and nymphs make small feeding punctures in leaves, mainly in the young leaves in shoot tips around the mid-vein.
- The punctures turn brown and eventually black.
- Leaves grow unevenly and become distorted and puckered.
- Nymphs also feed on young developing fruitlets causing similar puncture marks.
- As the fruitlets grow, irregular corky scars are formed and the fruit is misshaped.

Recognition

Adult
5.0-6.5 mm long. Bright green with a dusky yellow pubescence.

Nymph
Pale to bright green, tips of antennae orange-red. Fast moving

Egg
1.3 mm long, banana-shaped, cream, smooth and shiny. Inserted into the stems of plants.

Other pests with which the common green capsid may be confused

Other capsids

- Adults and nymphs of the apple capsid, Plesiocoris rugicollis, are very similar in appearance to those of the common green capsid.
- However, the apple capsid is uncommon in commercial apple orchards as it is sensitive to insecticides and does not occur on a wide range of other host plants.
- It is more common in unsprayed and organic apple orchards where it can be an important pest.

Green apple aphid and apple grass aphid

- These aphids have a green appearance and are found in the growing points of plants.
- However, aphids are slow moving or sedentary and often occur in colonies.
- They have honey tubes (siphunculi) whereas capsids do not.
- Aphids do not cause the chlorotic feeding puncture marks that are characteristic of capsids

Monitoring

Common green capsid is usually most abundant at the edges of orchards next to hedgerows, woodland or alder windbreaks and especially on apple trees with rootstock sucker growths. The tender shoots of such sucker growths are favoured sites for oviposition by adults the previous autumn and usually show signs of infestation first.

- The suckers on trees at the edges of orchards can be inspected in the dormant period for the characteristic bumps indicating where eggs have been inserted into the stem.
- The tips of rootstock sucker growths are often a good indicator of presence or absence of capsids in an orchard.
- They can be inspected on 2 3 occasions for damage from late green cluster to petal fall to determine when egg hatch has started.
- However, best practice is to remove them in winter (see Cultural control).

The best method of assessing levels of common green capsid is by using the beating method [hyperlink to this in the Introductory section, pest and disease assessment], which can detect the pest at low levels before significant damage is done.

- A sample of at least 25 (preferably 50) beats should be made per orchard when the pest assessment is done at the late blossom growth stage of apple.
- If any capsid is collected, beat sampling should continue to confirm the level present.
- The treatment threshold is 3 capsids per 50 beats.

- This method is time-consuming and seldom used in practice.
- As an alternative, the 25 trees should be visually inspected for signs of capsid feeding damage.
- If significant damage is detected, an insecticide treatment should be applied promptly at petal fall.

Work is in progress at East Malling Research and Natural Resources Institute currently to develop a pheromone lure and trap for monitoring common green capsid.

Forecasting

In the Netherlands, a phonological forecasting model has been developed for the common green capsid bug but it is not generally available.

- Work in the Netherlands has suggested that the time to monitor for the third instar nymphs which are most damaging to apples is when daily temperature sums above 4oC accumulated from 1 January amount to 568 2.05*DTs245 where DTs245 indicates the day on which 245 day-degrees is reached

Chemical control

A spray of an approved insecticide should be applied promptly at petal fall if damaging infestations are detected.

- Chlorpyrifos (various products) is known to be highly effective and will also control several other pests if applied at this time.
- Thiacloprid (Calypso) applied for control of rosy apple aphid at this stage will also control capsids as well as other petal fall pests including apple sawfly.
- Several other novel insecticides recently approved for control of aphids on apple and/or pear in the UK may have useful activity against capsid bugs including acetamiprid (Gazelle), flonicamid (Teppeki, Mainman) and thiamethoxam (Centric).

In other European countries in the past, mineral oil was applied just before bloom to kill the eggs just before emergence at around 200 day-degrees above 4oC after 1 January.

- This was effective but timing was crucial.
- Application too late resulted in leaf burning and too early was not effective.
- A local application was advised in places where damage by the capsids often occurred.

Cultural and biological control

Cultural control measures can significantly reduce common green capsid outbreaks in orchards.

- Rootstock sucker growths, which often harbour the pest, should be removed and destroyed in winter.
- Unfortunately, other beneficial capsid bugs, such as Blepharidopterus angulatus, deposit their eggs in the same place.
- Weeds growing in the herbicide strip under the tree, especially Compositae (e.g. mayweed), act as a summer host for the pest.
- These should be mown or destroyed before the second generation of adults mature in the late summer or autumn.
- Isolation from hedgerows, woodland and windbreaks reduces the incidence of the pest, but the benefits of proximity to such habitats and the shelter they provide is usually considered to be a net benefit, because of the occurrence of beneficial insects.

Natural enemies

Predatory insects and spiders
Capsid bugs appear to have few natural enemies. They are preyed on by nabid bugs and spiders.

Pathogenic fungi
Outbreaks of pathogenic fungal diseases during wet periods in summer can greatly reduce capsid populations.

Biological control

Biological control approaches have not been developed for common green capsid.

Biotechnological control

The female common green capsid is known to produce a sex pheromone which attracts males for mating. The chemical structures of the pheromone components have not been identified though some progress has recently been made in the Netherlands.

- The insect is attracted to white or yellow sticky traps, though these are not attractive enough in themselves to use for monitoring or control.
- When the pheromone has been characterised, it may be possible to use it for monitoring and even possibly for control in combination with coloured sticky traps.

Further reading

Blommers, L. H. M. 1997. Life history, seasonal adaptations and monitoring of the common green capsid Lygocoris pabulinus (L.)(Hemiptera: Miridae). Journal of Applied Entomology 121, 389-398.

Groot, A. T.2000. Sexual behaviour of the green capsid bug. PhD thesis, Wageningen University, The Netherlands. 156pp.

Petherbridge, F. R. & Thorpe, W. H. 1928. The common green capsid bug (Lygus pabulinus). Annals of Applied Biology 15, 446-472.

Flat scarlet mite (Cenopalpus pulcher (Canestini & Fanzago))

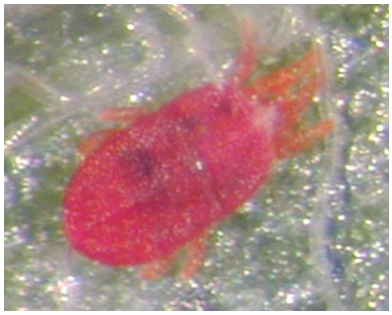
The flat scarlet mite has long been known as a minor pest of apples and occasionally pears in the UK. The females in particular are easily distinguished from other mites.

Flat scarlet mite is a relatively sedentary pest which tends to live in groups with a simple life cycle. It overwinters as fertilised females on the bark of apple. They become active in early spring, from April onwards, and invade the foliage and flower/fruit clusters in May.

The first eggs are laid on the wood late in April but subsequently eggs are laid along the midrib, beneath the leaf hairs. Eggs hatch from late June onwards.

Large numbers of mites feeding on foliage and developing fruits have a severe adverse affect on tree health and fruit quality.

Damage to the upper leaf surface starts with yellowing close to the veins which later develops into necrotic patches. Mites also cause bronzing damage to the lower leaf surface in much the same way as fruit tree red spider mite and apple rust mite.



Adult flat scarlet mite

Leaves develop necrotic areas at the base and shrivel and drop prematurely if infestation is severe. Mites feeding around the eye and sometimes the stalk of Cox and other varieties cause severe russet. Damage spreads onto the cheek in severe attacks.

Mating takes place in August and September. The males die and fertilised females migrate to the bark where they overwinter. There is one generation per year.

Populations have been increasing in apple orchards in recent years and damaging populations have developed in some orchards in the fruit growing areas in the UK so monitoring is important.

Flat scarlet mite damage to leaves

Flat scarlet mite infestation and damage to fruit

Control

- For chemical control of flat scarlet mite of the acaricides approved for use on apple in the UK, bifenthrin (Brigade) is by far the most effective and can give virtually 100% control of flat scarlet mite.
- Unfortunately, bifenthrin, being a persistent acaricidal synthetic pyrethroid, is extremely harmful to the orchard predatory mite Typhlodromus pyri. Treatment even once with bifenthrin is likely to result in severe subsequent outbreaks of fruit tree red spider mite and apple rust mite.
- It is possible that the worst effects of the bifenthrin on Typhlodromus pyri could be mitigated by application very early in the season. However, use of bifenthrin is also harmful to many other important orchard natural enemies and can cause flare ups of other pests, e.g. woolly aphid. For these reasons it should only be used as a last resort.
- Of the other acaricides fenpyroxmate (Sequel) appears the most effective giving >95% control of flat scarlet mite after about 6 weeks. A spray should be applied as soon as damaging infestations develop.
- Tebufenpyrad (Masai) is less effective giving perhaps about 50% control. With both these, fenpyroximate and tebufenpyrad are METI acaricides and only one application is allowed per annum. They are much less harmful to the orchard predatory mite Typhlodromus pyri.
- The efficacy of clofentezine (Apollo) has not been investigated but it is probable that if it has any effect, it will only control eggs and possibly young stages of flat scarlet mite.
- Resistance of flat scarlet mite to insecticides and acaricides has not been investigated or demonstrated. However, to minimise the risk of resistance, acaricides should be used as little as possible, alternating different products to reduce the risk of development of resistant strains.

Acaricides approved for use on apple which may control, at least partially, flat scarlet mite

Choice of products - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of	Safety to *Typhs*
bifenthrin	Brigade	pyrethroid	broad-spectrum	Red spider mite in apples and pears	harmful
clofentezine	Apollo	acaricide, ovicidal	selective	Winter eggs of fruit tree red spider mite on apple	safe
fenpyroximate	Sequel	METI acaricide	selective	Fruit tree red spider mite in apple	safe
tebufenpyrad	Masai	METI acaricide and aphicide	selective	Red spider mite in apples and pears.	us

Choice of insecticides - Safety factors

Read the label before applying any sprays

	Hazards				Harvest interval (days)	Max. no. sprays or dose	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
bifenthrin	no	h,i	ed	ed	u	2	30

clofentezine	no	u	u	s	28	1	u
fenpyroximate	no	h,i,e	ed	u	14	1	40
tebufenpyrad*	no	u	ed	d	7	1	18

Keys: d=dangerous, e=risk of serious damage to eyes, ed=extremely dangerous, h=harmful, ir=irritant, t=toxic u=unspecified or unclassified

METI = mitochondrial electron transport inhibitor

* not recommended for use with hand-held sprayers

Control in organic orchards

Emphasis should be placed on natural control by the orchard predatory mite *Typhlodromus pyri* (see 'Biological control').

- Application of foliar sprays of fatty acids (potassium soap) (Savona) or pyrethrum (various products), which are harmful to the orchard predatory mite, should be avoided unless absolutely necessary.
- Programmes of sprays of sulphur to control scab and mildew can also be harmful to the predatory mite though populations tolerant of the sulphur appear to develop eventually.

Further reading

Life cycle

Flat scarlet mite is a relatively sedentary pest which tends to live in groups.

- It overwinters as fertilised females on the bark of apple.
- They become active in early spring, from April onwards, and invade the foliage and flower/fruit clusters in May.
- The first eggs are laid on the wood late in April but subsequently eggs are laid along the midrib, beneath the leaf hairs. Eggs hatch from late June onwards.
- Mating takes place in August and September.
- The males die and fertilised females migrate to the bark where they overwinter.
- There is one generation per year.

Pest status

Flat scarlet mite is a minor pest of apple and sometimes pear of increasing importance in the UK.

Other hosts

Scarlet flat mite has also been recorded as a pest of plum and walnut in the UK and Europe and is known as a pest of quince in Egypt and Turkey.

Varietal susceptibility

Apple varieties vary considerably in their susceptibility to flat scarlet mite. Cox is the most susceptible variety commonly grown.

Distribution

Common and widely distributed and present at least at low levels in most apple orchards.

Recognition

Adult female
Up to 0.32mm long; bright red and flattened; legs very short.

Adult male
Similar to female, but smaller and paler in colour.

Egg
0.11 x 0.07 mm; bright red and oval.

Monitoring

Overwintering populations
Overwintering populations of females can be counted in winter. High numbers indicate high populations were present the previous season and present a threat for the following season.

In summer
The foliage of trees should be inspected for infestation or signs of damage from May onwards, looking out for eggs or mites on the undersides of leaves along the midrib and

for characteristic damage.

Forecasting

Forecasting methods for flat scarlet mite suitable for use by growers have not been developed.

Biological control

FAST has recently demonstrated that some control of flat scarlet mite can be made by introductions of predatory mites supplied by biocontrol companies, including Physoseiulus persimilis and Amblseius sp. However, the level of control was limited and the cost very high.

Natural enemies

Predatory mites
Several species of predatory mite in the family Phytoseidae prey on flat tree scarlet mite, including Typhlodromus pyri, the species which occurs in selectively sprayed apple orchards and is the key natural enemy of fruit tree red spider mite and apple rust mite because it has developed resistance to organophosphorus insecticides.

- If populations of the mite are conserved by avoiding the use of harmful insecticides, notably synthetic pyrethroids, fruit tree red spider mite and apple rust mite are seldom a problem.
- Typhlodromus pyri also appears to have a regulatory influence on populations of flat scarlet mite, though it does not seem able to give sufficient natural regulatory control to prevent serious outbreaks of flat scarlet mite.

Other predators

Flat scarlet mite is preyed on by several other generalist insect and mite predators such as anthocorids, mirids and spiders.

Biotechnological control

Biotechnological control methods have not been developed for flat scarlet mite.

Further reading

Jeppson, L. Keifer, H. & Baker, E. (Eds)1975. Mites Injurious to Economic Plants. University of California Press, 273pp, 281pp.

Fruit tree red spider mite (Panonychus ulmi (Koch))

Fruit tree red spider mite is an important secondary pest of apple.

The varieties Discovery, Gala and Worcester Pearmain are highly susceptible to fruit tree red spider mite.

Fruit tree red spider mite has a simple life cycle, overwintering as eggs on the bark, mainly around fruiting spurs. Eggs hatch in late April or May, around blossom time of apple. Young mites then invade the leaves and trusses.

There are five or six successive generations of adults, mainly on the undersides of leaves, before eggs are laid on bark in the autumn. All stages are readily recognised.

The pest is seldom a problem in orchards where the orchard predatory mite *Typhlodorums pyri* is established. It is important to regularly monitor levels of the pest and the preadator.

The presence of high populations of fruit tree red spider mite which causes leaf bronzing damage and fruit russeting is an indication of failure of proper integrated mite management. The predatory mite should be introduced, by transferring summer prunings in summer to newly planted orchards and to orchards where it is absent.

Pesticides harmful to the orchard predatory mite should not be used except as a last resort, as they cause outbreaks of rust and spider mites.

Overwintering fruit tree spider mite eggs

Chemical control

- Where high populations of overwintering eggs occur, a high volume spray of clofentezine (Apollo) should be applied before blossom and before hatching of overwintering eggs commences.
- Where damaging populations occur after blossom, a spray of fenpyroximate (Sequel), spirodiclofen (Envidor) or tebufenpyrad (Masai) should be applied.

Adult fruit tree red spider mite

Insecticides, acaricides and fungicides approved for use on apple or pear and which are recommended or likely to control, at least partially, fruit tree red spider mite

Choice of products - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of	Safety to *Typhs*
bifenthrin	Brigade	yrethroid	broad-spectrum	Red spider mite in apples and pears	harmful

clofentezine	Apollo	acaricide, ovicidal	selective	Winter eggs of fruit tree red spider mite on apple	safe
fenpyroximate	Sequel	acaricide	selective	Fruit tree red spider mite in apple	safe?
spirodiclofen	Envidor	ketoenol insecticide and acaricide	partially selective	Spider mites, rust mites, pear sucker and mussel scale on apple and pear	harmful
sulphur	various	fungicide & acaricide	selective	Scab and mildew on apples and pears. Gall mite on black-currants.	inter-mediate
tebufenpyrad	Masai	acaricide and aphicide	selective	Red spider mite in apples and pears.	safe?

Choice of insecticides - Safety factors

Read the label before applying any sprays

	Hazards				**Harvest interval (days)**	**Max. no. sprays or dose**	**Buffer zone Width (m)**
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
bifenthrin	no	h,i	ed	ed	u	2	30
clofentezine	no	u	h	U	28	1	u
diflubezuron	no	u	ed	U	14	2	sm
fenpyroximate	no	h,i	ed	U	14	1	40
spirodiclofen	no	h	h	D	14	1	30
sulphur	no	u	u	U	0	u	u
tebufenpyrad*	no	h	ed	D	7	1	18

Keys: d=dangerous, e=risk of serious damage to eyes, ed=extremely dangerous, h=harmful, ir=irritant, t=toxic u=unspecified or unclassified

CSI=chitin synthesis inhibitor

* not recommended for use with hand-held sprayers

Control in organic orchards

Emphasis should be placed on natural control by the orchard predatory mite *Typhlodromus pyri* (see 'Cultural and biological control'.

- Application of foliar sprays of fatty acids (potassium soap) (Savona) or rotenone (Derris), which are harmful to the predatory mite, should be avoided unless absolutely necessary.
- Programmes of sprays of sulphur to control scab and mildew can also be harmful to the predatory mite though populations tolerant of the sulphur appear to develop eventually.

Further reading

Life cycle

- Eggs overwinter on bark and are often most numerous on the smaller branches and spurs.
- Hatching begins in late April or May and is complete by mid-June.
- The young mites move to the undersides of leaves where they feed and develop.
- Five or more generations of mites occur in summer, adult females spreading the infestation as they move to fresh leaves.
- The mites form fine silken webs on which they can be carried from tree to tree by wind.
- In September, mites begin to deposit winter eggs on bark in response to the arrival of shorter days and cooler temperatures.

Pest status

Fruit tree red spider mite is an important secondary pest of apple which is much more troublesome if its key natural enemy, the orchard predatory mite *Typhlodromus pyri*, is not present. Fruit tree red spider mite is an infrequent pest of pear.

Other hosts

Also a frequent pest of plum and sometimes cherry. Also occurs on currants, gooseberry, cane fruits, walnut and many wild hosts e.g. *Malus, Prunus, Sorbus* spp.

Varietal susceptibility

Apple varieties vary considerably in their susceptibility to fruit tree red spider mite. Discovery, Worcester Pearmain and Gala are highly susceptible and are more frequently infested. Cox and Bramley are moderately susceptible.

Distribution

Common and widely distributed and present at least at low levels in most apple orchards.

Recognition

Adult female
Body oval, about 0.4 mm long, strongly convex and a dark red colour. The body is furnished with long setae arising from light coloured pinacula. These whitish spots at the base of the setae are diagnostic for this species.

Adult male
Similar in general appearance to female but smaller, yellow green to bright red and more or less pear-shaped, tapering posteriorly.

Immature stages
Pale yellowish-green to bright red. The first stage larvae has 6 legs

Eggs
Red, roughly spherical, 0.1 mm diameter, with the top drawn to a thin spike Overwintering eggs found on bark (guyed to the bark with threads of silken webbing) in winter and early spring, or on the undersides of leaves during summer.

Other pests or arthropods with which fruit tree red spider mite may be confused

Two-spotted spider mite
The two-spotted spider mite, *Tetranychus urticae*, is a generally abundant spider mite species which has a very wide host range and does occur on apple and pear trees especially in hot summers.

- High populations do not usually develop on apple or pear.
- The female is a green colour with two dark patches on the sides of the body.
- It causes similar damage to the fruit tree red spider mite.

Bryobia mites
The apple and pear bryobia mite, *Bryobia rubrioculus*, is superficially similar to the fruit tree red spider mite but is uncommon on sprayed fruit trees.

- Female bryobia mites have spatulate setae on their backs.

Tydeiid mites
The tydeiid mite, *Tydeus californicus*, commonly occurs in small numbers on the undersides of apple leaves usually near the main vein.

- It is smaller than fruit tree red spider mite and has a greenish yellow colour and does not cause significant damage.
- It provides an alternative food source for the orchard predatory mite *Typhlodromus pyri*.

Apple rust mite
The apple rust mite, *Aculus schlechtendali*, causes bronzing damage to the foliage of apple trees similar to that caused by fruit tree red spider mite but the rust mite is much smaller, light brown in colour and wedge-shaped.

- The rust mite and fruit tree red spider mite often occur in high numbers together because their key natural enemy, the orchard predatory mite *Typhlodromus pyri*, is absent.

Damage

Adults and nymphs have needle-like mouth-parts which they use to suck the sap from the surface cells of leaves and, sometimes, young developing fruitlets.

- The cells, which have their contents drained, are whitish in colour, causing a light speckling of the foliage.
- Later, as populations increase and damage intensifies, the leaves become dull green, brownish and finally, silvery bronze.
- Such foliage is brittle and may drop prematurely.
- Leaf damage is usually most evident in late summer and attacks are particularly severe in hot, dry summers.
- Heavy infestations affect yield and fruit bud formation for the following year.
- If large numbers of mites are present in spring, they can infest and feed on the developing fruitlets causing russeting.

Monitoring

If the orchard predatory mite *Typhlodromus pyri* is established and there is a stable equilibrium between the predator and its prey, detailed monitoring of red spider mite populations is not necessary.

- It is prudent to keep an eye out for leaf damage on susceptible varieties (e.g. Discovery, Worcester, Gala).
- If the predator/prey equilibrium is not established, then careful monitoring of the pest is necessary, especially during hot weather when populations and damage can increase rapidly.

Overwintering populations

- Overwintering populations of eggs on spurs and shoots can be counted in winter.
- High numbers indicate high populations were present the previous season and that a balanced equilibrium between pest mites and the orchard predatory mite has not been established.
- An average of more than 5 eggs per fruit bud, or the presence of eggs round vegetative buds in the extension growth, indicates a possible problem.
- However, the percentage of eggs that hatch successfully is somewhat variable and sometimes damaging infestations do not develop even if high numbers of overwintering eggs are present.

In summer

- A sample of at least 25 (preferably 50) expanded leaves should be examined per orchard on each occasion when a pest assessment is done.
- The number of leaves with 4 or more mites (motile stages plus eggs) should be counted.
- If 7 or more leaves in a sample of 50 leaves have 4 or more mites per leaf (equating to a mean of 2 mites per leaf), treatment with an acaricide is justified, particularly if the orchard predatory mite *Typhlodromus pyri* is absent, or present in only small numbers.

***Assessing numbers of* Typhlodromus pyri**

- When leaves are inspected for numbers of fruit tree red spider mite, the numbers of predatory mites present should be counted at the same time.
- The predatory mite often occurs along the main vein, particularly at the point where the main vein joins with a side vein, sheltering in the groove between the veins and the leaf lamella.
- The predatory mite is a pale whitish-straw colour, sometimes with red gut when a red spider mite has been consumed and is pear shaped with a smooth body with 17 pairs of setae.
- It often moves rapidly over the leaf.

Forecasting

Forecasting methods for fruit tree red spider mite suitable for use by growers have not been developed. However, population increase can be very rapid in hot weather and bronzing damage to the undersides of leaves can intensify rapidly.

Chemical control

Chemicals that are used for control of mites on apple and pear are not systemic. Higher volume spray applications to give good cover are needed to get the best results.

- Bifenthrin (Talstar), clofentezine (Apollo), fenpyroximate (Sequel), spirodiclofen (Envidor) and tebufenpyrad (Masai) are approved for control of fruit tree red spider mite on apple.
- With the exception of clofentezeine (Apollo) and fenpyroximate (Sequel) they are also approved for the control of fruit tree red spider mite on pear, though the pest is seldom a problem on pear in the UK.
- Bifenthrin (Talstar) is harmful to the orchard predatory mite *Typhlodromus pyri* and their use should be avoided.
- Clofentezine (Apollo) is an ovicide. If significant populations of overwintering eggs are present, a spray may be applied up to just before blossom before egg hatch commences.
- It is important to use a high spray volume to thoroughly wet the bark as only eggs that are directly intercepted by spray are likely to be controlled.
- Application is best made in the late dormant period before green cluster as it is easier to get good spray cover before the rosette leaves develop.
- For damaging summer infestations, fenpyroximate (Sequel), spirodiclofen (Envidor) or tebufenpyrad (Masai) are the available choices.
- The product chosen will depend on other pests to be controlled and the history of previous use of acaricides (see below).
- These acaricides are best applied when most eggs have hatched but before breeding infestations become established.
- Higher volume sprays to achieve good cover are more effective. Tebufenpyrad (Masai) or spirodiclofen (Envidor) should not be applied before 90% petal fall and after bee activity has ceased because of the high risk to bees.

Resistance to acaricides and avoiding its development

- The fruit tree red spider mite readily develops strains resistant to insecticides and acaricides.
- The mite is now universally resistant to organophosphorus insecticides.
- The best way to avoid the development of resistance is to ensure that the orchard predatory mite *Typhlodromus pyri* is conserved so that acaricide use is unnecessary.
- Acaricides should be used as little as possible, alternating different products to reduce the risk of development of resistant strains.

Cultural and biological control

Young trees from the nursery used to plant new orchards are often infested with apple rust mite and/or fruit tree red spider mite and do not have established populations of the orchard predatory mite *Typhlodromus pyri*.

- Damage by fruit tree red spider mite and often apple rust mite can occur rapidly in the first season after planting whereas the pest may be unimportant in other

established orchards on the farm.

- Steps should be taken to ensure the nursery trees are not heavily infested with pest mites before they are purchased and delivered to the farm.
- In orchards, hot, dry situations favour rapid population increase of apple rust mite.
- Overall bare soil orchards should be avoided.

Natural enemies

The orchard predatory mite Typhlodromus pyri

- Several species of predatory mite in the family Phytoseidae prey on fruit tree red spider mite, but *Typhlodromus pyri* is the species which occurs in selectively sprayed apple orchards and is the key natural enemy of fruit tree red spider mite because it has developed resistance to organophosphorus insecticides.
- The predatory mite is also the key natural enemy of apple rust mite.
- If populations of the mite are conserved by avoiding the use of harmful insecticides, notably synthetic pyrethroids, fruit tree red spider mite and apple rust mite are seldom a problem.

Other predators

- Fruit tree red spider mite is preyed on by several other generalist insect and mite predators such as anthocorids, mirids and spiders and the stigmaeid mite *Zetzellia mali*.

Biological control

Establishment of the orchard predatory mite, *Typhlodromus pyri*, is crucial. Unless the predator is established, regular outbreaks of fruit tree red spider mite and apple rust mite are inevitable and these can be very damaging and difficult and costly to control.

- Once the predator is established and the biological equilibrium between the predatory mite and the pest mite has stabilised, fruit tree red spider mite and apple rust mite seldom cause problems, providing the equilibrium is not disturbed by the use of pesticides harmful to the predatory mite.
- The predatory mite will establish naturally in apple orchards but this can be a slow process.
- Pest mite infestations are present and can develop rapidly on newly planted trees which do not have established populations of the predatory mite (often because they have been sprayed with predator-harmful pesticides in the nursery e.g. with frequent sprays of carbendazim to control canker).
- Where the orchard predatory mite is absent, e.g. in newly planted orchards, it should be introduced in summer by transferring extension shoots from established orchards where the predatory mite is abundant.
- Summer prunings may be used. Ideally, at least one shoot should be placed amongst the foliage in each tree of the orchard where the predator is to be introduced.

Biotechnological control

Biotechnological control methods have not been developed for fruit tree red spider mite.

Further reading

Helle, W. & Sabelis, M. W. (Eds) 1985. Spider mites, their biology, natural enemies and control. World Crop Pests Volumes 1A and 1B. Elsevier, Amsterdam, 405pp, 458pp.

Fruit tree tortrix moth (Archips podana (Scolopi)

Fruit tree tortrix moth is a moderately important pest of apples and pears in the UK.

The life cycle is simple with the pest overwintering as a second or third instar larva which emerges in spring after bud burst and feeds on the trusses. Pupation occurs after blossom and first generation adults fly in June and early July.

Eggs are laid in batches on foliage and hatch after 2-3 weeks. Adults are readily recognised but larvae may be confused with other caterpillar species.

Larvae feed in leaf rolls and on the surface of fruits making the characteristic damage of small holes in the flesh. Later in the season, near to harvest, larvae make larger surface excavations in the flesh of fruits. There is a partial second generation in August and September.

The pest should be monitored with pheromone traps weekly from petal fall of apple to the end of August. The economic threshold for treatment is >30 moths per trap per week.

Adult fruit tree tortrix moth

Fruit tree tortrix moth larva

Control

Several insecticides are approved for control of tortrix moth and/or other caterpillars on apple and/or pear in the UK.

- The pest may be controlled with a spray of *Bacillus thuringiensis* (Dipel), chlorpyrifos (various products.), indoxacarb (Steward), methoxyfenozide (Runner) or spinosad (Tracer), applied to coincide with egg hatch usually in late June or July about 2 weeks after the threshold pheromone trap catch is exceeded.
- Diflubenzuron (Dimilin), a selective insecticide, is also effective against fruit tree tortrix moth.
- It should be applied at the start of egg laying, i.e. as soon as the pheromone trap threshold is exceeded. It is not effective against the summer fruit tortrix moth.
- Synthetic pyrethroids are highly effective but their use should be avoided as they are harmful to predatory mites and other beneficial insects.
- Nicotine is also approved but is toxic and of short persistence and its use should be avoided. Note that approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.
- Chlorpyrifos (various products.), diflubenzuron (Dimilin), indoxacarb (Steward), methoxyfenozide (Runner) or spinosad (Tracer) will also control codling moth.
- Codling moth flies slightly earlier than fruit tree tortrix moth but sprays of these insecticides applied for codling moth usually also give good control of fruit tree tortrix moth.
- The juvenile hormone analogue insect growth regulator fenoxycarb (Insegar) applied 2–3 weeks after petal fall will also control fruit tree tortrix though it is not specifically recommended for this purpose.

- Delaying the spray until after petal fall will reduce the efficacy of fenoxycarb (Insegar) against summer fruit tortrix against which it is specifically used and recommended.

Small holes in fruits caused by tortrix larval feeding

Insecticides approved for control of codling, tortrix moths or caterpillars on apple and pear

Surface grazing to fruits by fruit tree tortrix moth larvae

Choice of insecticides - efficacy factors

Active ingredient	Trade names	Class[1]	Selectivity	Label rec's[2]	Safety to *Typhs*	Suggested interval between sprays (days)
Bacillus thuringiensis	Dipel	bacterial insecticide	selective to caterpillars	c (SOLA)	safe	3-14
bifenthrin	brigade	pyrethroid	broad-spectrum	Red spider mite	harmful	14-21
chlorpyrifos	Dursban, etc.	OP	broad spectrum	c, cm, t	safe	14-21
cypermethrin	various	pyrethroid	broad spectrum	c, cm, t	harmful	14-21
deltamethrin	Decis	pyrethroid	broad spectrum	cm, t	harmful	21
diflubenzuron	Dimilin	CSI	selective	c, cm, ftt	safe	28
indoxacarb	Steward	oxadiazine	selective	c, cm, ftt, sft	u	10-14
fenoxycarb	Insegar	JHA	selective	sft	safe	21
methoxyfenozide	Runner	MAC	selective	c	safe	u
nicotine*	various	alkaloid	broad spectrum	c	harmful	7
spinosad	Tracer	neural blocker	selective	C, cm, ftt,sft	safe	10

Choice of insecticides - Safety factor

Read and and follow the label before applying any sprays

	Hazards[2]				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
Bacillus thuringiensis	no	u	u	u	0	u	u
bifenthrin	no	h,i	ed	ed	u	2	30
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
diflubenzuron	no	u	u	u	14	3	u
indoxacarb	no	h	ed	u	7	3	15
fenoxycarb	no	u	d	d	42	2	18
methoxyfenozide	no	u	u	u	14	3	5
nicotine*	no	t, h	d	h	2	u	u
spinosad	no	u	ed	u	7	4	40

Keys: [1]OP=organophosphate, CSI=chitin synthesis inhibitor, JHA=juvenile hormone analogue

[2]c=caterpillars, ftt=fruit tree tortrix, sft=summer fruit tortrix, t=tortrix

[3]d=dangerous, ed=extremely dangerous, h=harmful, i=irritant, t=toxic, u=no hazard specified

* approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Control in organic orchards

Fruit tree tortrix moth often causes significant fruit damage in organic orchards.

- If control measures are necessary, sprays of *Bacillus thuringiensis* (Dipel) or, if it is permitted in organic production, spinosad (Tracer) should be applied in the same way as in conventional orchards (see 'Biological and chemical control').

Further reading

Life cycle

There is one main generation per annum in the UK with a partial second generation in late August and September. The second generation is more marked in hot years which favour rapid development of the first generation.

- Larval development has seven instar stages.
- The pest overwinters mainly as a third, sometimes second, instar larva in a silken hibernaculum beneath a bud scale, between a dead leaf and a twig or spur or in crevices in the bark or other shelter.
- After emergence in spring, shortly after bud-burst, individual larvae feed in or amongst the buds, often tying them and rosette leaves together with webbing.
- Fifth instar larvae feed on developing fruitlets, making cavities in the receptacle, which later heal to form corky scars characteristic of early caterpillar feeding.
- Sixth and seventh instar larvae tend to live on foliage.
- Larvae pupate when fully fed, normally in late May or early June.
- First generation adult moths emerge three weeks later, normally in late June and early July, and often a week or two after the flight of codling moth has exceeded the threshold.
- Eggs are laid in batches on the foliage. These hatch in 2-3 weeks depending on temperature (see 'Forecasting' below).
- Cool and wet weather conditions at the time of moth flight and/or during egg-hatch limit population increase.
- The tiny first instar larvae spin webs of silk, usually on the undersides of leaves close to the veins leaves, often at a junction between the main and a side vein, and begin to feed.
- They feed on leaves, often between two spun leaves or where two or more fruits are touching or in the calyx cavities of fruits.
- A greater proportion of third instar larvae feed on fruits. Most larvae overwinter in this third instar stage.
- A proportion of more advanced larvae complete their development in August and a partial second generation of adults occurs in August and September.
- These hatch in September or early October and the young larvae feed on leaves overwintering if they reach the second or third instar development stage.

Pest status

Moderately important pest of apple and pear. Attacks foliage and fruit.

Other hosts

Highly polyphagous, the larvae feed on a wide range of trees and shrubs including fruit trees and bushes.

Varietal susceptibility

All varieties are susceptible but those with fruits that are short stalked and/or which hang in clusters, tend to suffer the most damage.

Distribution

Common and widely distributed. One of the most abundant species associated with fruit trees.

Recognition

Adult(resting)
Length 9-12 mm, forewings purplish ochreous with distinctive dark reddish brown markings.

Egg
Flat, almost circular, light green. Black centre when mature. Laid in scale-like batches on leaves.

Larvae
Up to 22 mm long. Yellow-green, olive green or dark green, usually with a black head, though head colour is not diagnostic. Last body segment breathing pores (spiracle) larger than rest. Spins fine webbing and often occurs in leaf rolls or beneath a leaf tied to fruit.

Other pests with which fruit tree tortrix moth may be confused

Larvae of several leaf-rolling tortrix moths are very similar and are difficult to distinguish from each other.

- Larvae of the summer fruit tortrix moth, *Adoxophyes orana,* occur commonly in orchards in the UK, especially in the south and east, and are particularly difficult to distinguish from those of the fruit tree tortrix moth.

Damage

- Larvae are leaf-rollers but damage to foliage is unimportant.
- Damage to fruits occurs at different times during fruit development:
- Overwintered larval feeding cavities in the receptacle of flowers and young fruitlets later heal to form corky scars characteristic of early caterpillar feeding on mature fruits.
- Young caterpillars make small, shallow holes in the skin of fruits in July and August.
- Larger caterpillars graze shallow irregular patches in the skin, especially at the point where fruits are in contact.

Monitoring

Pheromone traps
The flight activity of male moths (along with that of the codling moth and summer fruit tortrix moth) should be monitored using sex pheromone traps (a different trap is used for each species). The delta design is used widely.

- Traps should be set out in orchards shortly after blossom.
- Each orchard should be individually monitored with a trap. The traps should be hung from the branch of a tree at mid canopy height in the centre of the orchard and oriented to allow flow through of the prevailing wind.
- The number of moths should be recorded weekly, and captured moths removed.
- Lures should be changed every 4-6 weeks as recommended by the manufacturer. Sticky bases should be changed if their effectiveness declines.
- The economic threshold is considered to be 30 moths per trap per week, though this may be a conservative estimate.

- Temperature sums to predict egg hatch to determine correct timing of egg hatch sprays should be started from the date when the first threshold catch is recorded.

Fruit damage inspection
Inspecting fruits for damage, either whilst developing on the tree, at harvest or during grading (remembering that badly damaged fruit may have been discarded at harvest), indicates if populations have been high and whether treatment is likely to be required for the next generation or the next season.

Forecasting

The rate of development of each of the development stages of fruit tree tortrix moth is only completed when a known heat sum has accumulated. Heat sums can be calculated each day from the daily maximum and minimum air temperature. PESTMAN can be used to give approximate predictions of the timing of occurrence of each of the life stages of the pest.

Control methods

Chemical control

Control with chlorpyrifos (various products), indoxacarb (Steward), spinosad (Tracer), synthetic pyrethroids or nicotine (various products):

The organophosphorus insecticide chlorpyrifos (various products), indoxacarb (Steward), spinosad (Tracer), nicotine (various products) and several pyrethroid insecticides are approved for control of tortrix moth and other caterpillars in apple and/or pear orchards in the UK.

- Synthetic pyrethroid insecticides, which are very effective against the pest, should be avoided because they are harmful to predatory mites and other natural enemies.
- Nicotine is toxic and of short persistence and its use should be avoided.
- A pre-blossom spray of chlorpyrifos, often applied to control early season caterpillars, will reduce populations of overwintered fruit tree tortrix moth caterpillars, but may not be sufficiently effective to prevent damaging populations developing in summer.
- First generation caterpillars may be controlled by a spray of one of these insecticides timed to coincide with the onset of egg hatch.
- The first threshold pheromone trap catch (30 moths/week) indicates the date when egg laying commences.
- The first insecticide spray should be applied about 2 weeks later.
- These insecticides will also control codling moth which flies slightly earlier than fruit tree tortrix moth and sprays of these insecticides applied for codling moth usually also give good control of fruit tree tortrix moth.

Control with the chitin synthesis inhibitor insecticide diflubenzuron (Dimilin):
Diflubenzuron (Dimilin) is approved for control of tortrix moths on apple and pear and is effective against the fruit tree tortrix moth.

- It is ineffective against the summer fruit tortrix moth but is highly effective against codling moth. It is a selective insecticide and is valuable in Integrated Pest Management.
- For control of fruit tree tortrix moth, a spray should be applied as soon as the threshold pheromone trap catch is reached.
- A spray of diflubenzuron against codling moth often gives good incidental control of fruit tree tortrix moth.

Control with the juvenile hormone analogue insecticide fenoxycarb (Insegar):
A post-blossom spray of the juvenile hormone analogue insecticide fenoxycarb (Insegar), recommended for control of the summer fruit tortrix moth, will also control fruit tree tortrix moth.

- A delay in treatment of 2-3 weeks after blossom of apple is necessary to get the best results, which will greatly decrease the effectiveness of the insecticide against summer fruit tortrix moth.
- The insecticide will also control codling moth by ovicidal action.

Control with moulting accelerating compound methoxyfenozide (Runner)):
Methoxyfenozide (Runner) is highly effective against tortrix moth caterpillars including fruit tree tortrix moth.

- It may be applied before blossom to control overwintered caterpillars or at or after egg hatch to control caterpillars of the summer generations.
- It also effective against codling moth and *Blastobasis decolorella*).

Control with Bacillus thuringiensis:
See 'Biological control' below.

Insecticide resistance

Resistance of fruit tree tortrix to insecticides is not known to occur.

Cultural control

Trees which have a dense canopy and vigorous shoot growth tend to support greater populations of caterpillars. If shoot growth then ceases when caterpillars are young, due to water stress and/or a heavy fruit load, the caterpillars tend to move to feed on fruits, especially those in clusters, and damage intensifies.

- Avoiding this situation by tree management reduced losses.
- Furnishing the trees with artificial refuges for earwigs and other insect predators (see rosy apple aphid) is likely to help reduce young caterpillar populations.

Natural enemies

The fruit tree tortrix moth has many natural enemies. Parasitic wasps reduce populations to comparatively low levels in unsprayed orchards but parasites are less abundant in orchards sprayed with broad-spectrum insecticides.

Insectivorous birds
Tits especially pick overwintering larvae from bark, but do not forage specifically for the pest unless population densities are very high and for this reason are of limited value only.

Egg parasites
Parasitic wasps (*Trichogramma* sp.) attack the eggs but parasitism rates are generally low.

Larval and pupal parasites
Several parasitic wasps and flies parasitise fruit tree tortrix moth larvae or pupae.

- Common species are *Meteorus ictericus* which develops inside the host larva before exiting the larva at the third instar stage, spinning a cocoon nearby. The host larva is not devoured entirely and remains alive for a period of time, eventually dying without further development.
- *Apanteles ater* is another common internal larval parasite.

Predatory insects

Earwigs and predatory mirid and anthocorid bugs feed of eggs and young larvae.

Virus diseases
No virus diseases of fruit tree tortrix moth have been reported.

Biological control

A programme of weekly sprays of *Bacillus thuringiensis* (Bt) (Dipel DF) throughout the egg hatch period gives fairly good control but is costly compared to other insecticides.

- Bt has to be ingested to act and is most effective in warm weather when caterpillars are feeding actively.
- The bacterium produces a crystalline toxin.
- The insect dies from the effects of this toxin rather than from pathogenesis due to the bacterium.
- Bt is of short persistence as it is degraded by heat and UV light.
- It is most effective against newly hatched larvae before they form leaf rolls in which they feed internally and are inaccessible to sprays.
- The first spray should be applied at the onset of egg hatch which should be determined from pheromone trap catches and egg development sums calculated from the daily maximum and minimum air temperature.
- Bt is not detected by conventional pesticide residue analysis.

Biotechnological control

Mating disruption systems for tortrix moths in apple orchards are used in other European countries and are effective against fruit tree tortrix moth providing initial populations are low.

Further reading

Hey, G. L. & Massee, A. M. 1934. Tortrix investigations in 1933. Annual report for East Malling Research Station 1933, 228-230.

Van der Geest, L. P. S. & Evenhuis, H. H. (Eds). 1991. *Tortricid Pests, Their Biology, Natural Enemies and Control* . World Crop Pests, Vol. 5. Elsevier, Amsterdam.

Green apple aphid (Aphis pomi Degeer)

Green apple aphid is a common but minor pest of apple, which also attacks pear. It is most important on young trees. As the name implies it is bright green in colour and readily distinguished from other aphid pests of apple.

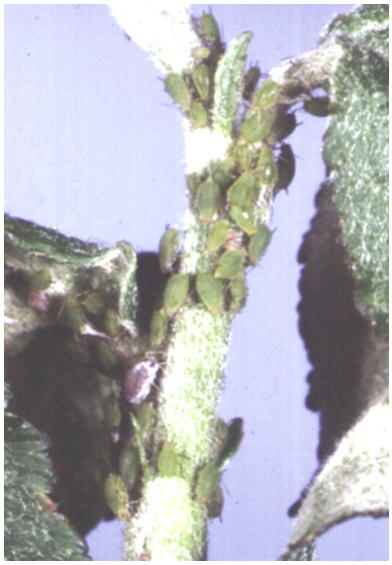
The life cycle starts when the aphid hatches in April at green cluster from overwintered eggs on the bark but the spring colonies that develop in shoot tips are of little importance.

Winged forms develop in summer, which migrate to the growing shoots of other apple trees.

Large, dense colonies develop along the lengths of the shoots from these migrants in summer and it is these that are damaging. The colonies have a strong distinctive smell.

Fruits in the vicinity of and below colonies become heavily contaminated with honeydew which becomes blackened by sooty mould and cast aphid skins. The colonies are usually attended by black ants.

The severity of infestation by green apple aphid should be determined in each orchard when pest assessments are done from late June to the end of August. Application of an insecticide to control green apple aphid should be considered if more than 10% of shoots have infestations causing leaf curling.



Green apple aphid

Control

Many insecticides are approved for control of aphids on apple and pear but if aphids are the only pests that need to be controlled pirimicarb (Aphox etc.) or flonicamid (Teppeki, Mainman) are the preferred choices in conventional orchards as they are selective and partially systemic.

- The neonicotinoids acetamiprid (Gazelle), thiacloprid (Calypso) and thiamethoxam (Centric) are also highly effective. They will also control various other pests such as mussel scale (all), woolly aphid (acetamiprid, thiamethoxam) and thiacloprid (Calypsos) is considered to have some activity against codling moth. However, possible side effects on natural enemies including earwigs should be considered.
- Chlorpyrifos (various products) will also control several other pests such as codling moth or tortrix moth caterpillars but is not a favoured product to use in mid or late summer by some multiple retailers because of the risk of detectable (though below MRL) OP residues on harvested fruits.
- Use of synthetic pyrethroids, which are harmful to natural enemies, or nicotine, which is toxic, should be avoided. Approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.

Insecticides approved for control of aphids on apple

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of -	Safety to *Typhs*
acetamiprid	Gazelle	neonicotinoid	broad-spectrum, systemic	Aphids and Whitefly	safe
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars,	safe

				sawfly, capsids etc.	
cypermethrin	various	pyrethroid	broad spectrum	Aphids, capsids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
fatty acids	Savona	soap	broad spectrum	Aphids, scale insects	harmful
flonicamid	Teppeki, Mainman	neonicotinoid	selective	Aphids and woolly aphid	safe
nicotine*	various	alkaloid	broad spectrum	Aphids including woolly aphid, caterpillars, sawflies	harmful
pirimicarb	Aphox etc.	carbamate	selective aphicide, trans-laminar	Aphids	safe
thiacloprid	Calypso†	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids and sawfly, though not caterpillars or woolly aphid)	safe
thiamethoxam	Centric	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe

Choice of insecticides - Safety factors

	Hazards				**Harvest interval (days)**	**Max. no. sprays**	**Buffer zone Width (m)**
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
acetamiprid	no	u	h	u	14	2	20
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
fatty acids	no	u	h	u	0	u	sm

flonicamid	no	u	h	u	21	3	sm	
nicotine*	no	t, h	d	h	2	u	sm	
pirimicarb	yes	t, c	h	-	3	u	sm	
thiacloprid†	no	h, i	h	h	14	2	30	
thiamethoxam	no	h	h	d	14	2	sm	
h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, c=closed cab required for air assisted sprayers, sm=statutory minimum of 5 m for broadcast airassisted sprayers u=uncategorised/unclassified/unspecified † not approved for use on pear *approval for use and storage of all products containing nicotine is allowed only until 08 June 2010								

Control in organic orchards

Green apple aphid should be tolerated in established organic apple orchards because the pest only causes minor damage.

- Emphasis should be placed on cultural control measures such as the provision of artificial refuges for earwigs and lacewings and of flowering herbs in and around the orchard to encourage predatory insects.
- Where significant damage is being caused especially to young trees, as a last resort, localised, high volume sprays of fatty acids (potassium soap) (Savona) should be applied when damaging infestations develop on young trees in summer if necessary.

Further reading

Life cycle

- Overwintered eggs on the bark of apple trees hatch in April, rather later than those of the apple grass aphid or the rosy apple aphid.
- The nymphs feed on the undersides of the leaves mainly in the tips of young shoots. Winged aphids develop in June and throughout the summer.
- The winged aphids migrate to other apple trees and these are largely responsible for the colonies that develop in extension shoots in summer. Wingless sexuals form in the autumn and eggs are laid on the bark of young shoots, often in considerable numbers.
- Colonies are usually attended by the common black ant *Lasius niger*, which feeds on the honeydew produced by the aphids but also defend the colonies from attack by natural enemies.

Pest status

Green apple aphid is a common but minor pest of apple which also attacks pear. It is most important on young trees.

Other hosts

Pear and quince are also attacked.

Varietal susceptibility

All apple varieties are susceptible to infestation by the aphid.

Distribution

Widespread and common.

Damage

Spring attacks are unimportant. Large colonies may develop in the shoots in summer, causing considerable leaf curl, stunting and shoot tips may be killed.

- This damage is important on nursery stock and young trees. In established orchards, infestation of up to 10% of shoots can be tolerated (see 'Monitoring').
- However, if colonies are large, fruit beneath may be contaminated with honeydew and cast skins.
- Colonies are usually attended by the common black ant *Lasius niger*, which feeds on the honeydew produced by the aphids and helps to prevent contamination of the foliage.

Recognition

Egg
Shiny black and found on the bark of apple trees on rough bark round buds.

Adult
Bright or yellowish green. Honey tubes (siphunculi) moderately long (about the same length as the distance between their bases), black or dark brown. Cauda ('tail') finger-like.

Other pests with which the pest may be confused

Apple grass aphid

- This is the other aphid species that occurs commonly on apple and which has a green colour.
- However, the apple grass aphid has darker green longitudinal stripes and has pale green, short (much shorter than the separation between their bases), honey tubes which are flanged at the tip.
- Apple grass aphid is abundant on the rosette leaves and amongst trusses from green cluster to shortly after blossom whereas the green apple aphid is more troublesome in summer.

Monitoring

The severity of infestation by green apple aphid should be determined in each orchard when pest assessments are done from late June to the end of August.

- Examine the growing shoots (preferably all, but examining two shoots per tree carefully) in at least 25 trees per orchard.
- Application of an insecticide to control green apple aphid should be considered if more than 30% of shoots are infested with one or more aphids or if 10% of shoots have infestations causing leaf curling.

Forecasting

Useful forecasting models for green apple aphid have not been developed.

Chemical control

Control of infestations in shoots in summer
A spray of an approved insecticide should be applied as soon as damaging infestations are detected (see 'monitoring').

- Many insecticides are approved for control of aphids on apple and pear but if aphids are the only pests that need to be controlled, pirimicarb (Aphox etc.) or flonicamid (Teppeki, Mainman) are the preferred choices in conventional orchards as they are selective and partially systemic.
- The neonicotinoids acetamiprid (Gazelle), thiacloprid (Calypso) and thiamethoxam (Centric) are also highly effective. They will also control various other pests such as mussel scale (all), woolly aphid (acetamiprid, thiamethoxam) and thiacloprid (Calypsos) is considered to have some activity against codling moth. However, possible side effects on natural enemies including earwigs should be considered.
- Chlorpyrifos (various products) will also control several other pests such as codling moth or tortrix moth caterpillars but is not a favoured product to use in mid or late summer by some multiple retailers because of the risk of detectable (though below MRL) OP residues on harvested fruits.
- Use of synthetic pyrethroids, which are harmful to natural enemies, or nicotine, which is toxic, should be avoided.
- Approval for use of nicotine will be withdrawn from June 2009.

Control from applications of aphicides in spring

- A spray of an approved insecticide is often applied before blossom at the green cluster to pink bud growth stage against rosy apple aphid and/or apple grass aphid.
- Such applications will also control green apple aphid present at that time and will reduce, but not eliminate, the number of colonies that develop from winged migrants in summer.

Cultural control

There are few specific cultural controls for green apple aphid.

- Natural enemies should be encouraged by avoiding the use of broad-spectrum insecticides and by providing flowering plants in and around the orchard.
- Artificial refuges can be provided for predators.
- High nitrogen levels and other factors that favour vigorous shoot growth favour green apple aphid and should be avoided.

Natural enemies

Predatory insects and spiders

- A wide range of predatory insects, including anthocorid, mirid and nabid bugs, ladybird adults and larvae, hoverfly, predatory midge and lacewing larvae and spiders feed on green apple aphid.
- However, the black ant, *Lasius niger*, is usually attendant in green apple aphid colonies and defends them from predators.

Parasitic wasps
The parasitic wasp *Trioxys angelicae* is the most important parasitoid of green apple aphid, though the aphid is parasitised by many other species including *Ephedrus persice, Ephedrus platigator, Lipolexis gracilis, Lysiphlebus fabarum, Praon volucre* and *Trioxys auctus*.

- The parasites lay their eggs (usually singly) in the body of the aphid which continue to feed during the early stages of development of the parasite.
- The parasites eventually pupate within or beneath the skeleton of the aphid forming a so-called 'aphid mummy'. *Trioxys angelicae* also parasitises rosy apple aphid and rosy leaf curling aphid.
- Although parasitic wasps are common natural enemies of green apple aphid, they are not usually abundant enough to greatly reduce aphid populations.

Fungal parasites:
Outbreaks of fungal disease (*Entomophthora planchoniana* and *E. fresenii*) have been recorded in green apple aphid colonies. Outbreaks occur in warm, humid or wet conditions.

Biological control

Biological control approaches have not been developed for green apple aphid.

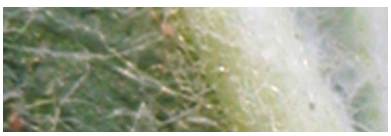
Further reading

Barbagallo, S., Cravedi, P, Passqualini, E, Patti, I, & Stroyan, H. L. G. 1997. Aphids on the principal fruit bearing crops. Bayer, Milan.123pp

Minks, A. K. & Harrewijn, P. 1987. Aphids, their biology, natural enemies and control. World Crop Pests, Volumes 2A, 2B and 2C. Elsevier, Amsterdam.

Leafhoppers (Edwardsiana crataegi (Douglas) and other species)

Leafhoppers are minor pests of apple with a life cycle that involves overwintering as eggs and hatch in the spring to feed on the undersides of leaves causing speckling damage.



Very large populations of adults and nymphs can build up in apple orchards over a number of seasons if effective insecticidal control measures are not applied occasionally. Leaf speckling damage increases as the season progresses and can give the tree a bleached appearance by the end of the season. Intensive damage reduces

vigour and fruit size and adversely affects fruit bud formation.

Fruit surfaces become contaminated by numerous small brown spots of excrement. This contamination is easily washed away by water, including by rain, during post-harvest drenching or grading.

Leafhoppers are small and usually green or yellow in colour and are easily distinguished from aphids as they readily jump and fly.

Leafhopper populations are best monitored by visual inspection for the characteristic speckling damage and for the leafhoppers themselves which are often present on the undersides of damaged leaves.

A spray of an approved insecticide should be applied in summer against adults and nymphs if leaf damage starts to become unsightly and is increasing.

Control

- Nicotine is the only insecticide recommended by the manufacturer for control of leafhoppers on fruit trees. However, it is toxic to humans and is harmful to predatory mites and its use should be avoided. Approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.
- The commonest leafhopper species on apple appears widely resistant to chlorpyrifos (Dursban).
- Thiacloprid (Calypso), though only specifically recommended by the manufacturer for control of aphids, will give incidental control of leafhoppers and it is likely that other neonicotinoids such as acetamiprid (Gazelle) and thiamethoxam (Centric) are similarly effective.
- Synthetic pyrethroids are also effective but they are harmful to the orchard predatory mite *Typhlodromus pyri* and many other natural enemies and should only be used as a last resort where no alternative can be used.

Control in organic orchards

Emphasis should be placed on cultural control methods.

- None of the insecticides permitted for use in organic production and approved for use on apple is recommended for control of leafhopper.

Leafhopper nymph

Leafhopper adult

Insecticides approved for use on apple that are recommended or likely to be effective for control of leafhoppers on apple and/or pear

Leafhopper speckling damage

Leafhopper frass on Fiesta fruit

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of-	Safety to *Typhs*
acetamiprid	Gazelle	neonicotinoid	broad-spectrum, systemic	Aphids and Whitefly	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful

deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
thiacloprid	Calypso†	chloro-nicotinyl	broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids, leafhoppers and sawfly, though not caterpillars or woolly aphid)	safe
thiamethoxam	Centric	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe
nicotine*	various	alkaloid	broad spectrum	Leafhoppers, aphids, caterpillars, sawflies	harmful

Choice of insecticides - Safety factors

Read and follow the label before applying any sprays

	Hazards[2]				**Harvest interval (days)**	**Max. no. sprays**	**Buffer zone Width (m)**	
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees				
acetamiprid	no	u	h	u	14	2	20	
cypermethrin	no	h, i	ed	d	0	5	18	
deltamethrin	no	h, i	ed	d	0	u	18	
nicotine*	no	t, h	d	h	2	u	sm	
thiacloprid	no	h, i	h	h	14	2	30	
thiamethoxam	no	h	h	d	14	2	sm	

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, t=toxic, c=closed cab required for air assisted sprayers, u=uncategorised/unclassified/unspecified

† not approved for use on pear

* approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Further reading

Life cycle

The commonest species on apple, *Edwardsiana crataegi*, overwinters as eggs laid in the autumn beneath the bark of twigs or small branches of fruit trees.

- Eggs hatch in April to early May.
- Nymphs feed until mid-summer.

- New adults appear in late July and August, laying eggs in or near the mid-vein on the undersides of leaves.
- Second generation nymphs occur from August onwards and become adults in the autumn.

Edwardsiana rosae has a similar life cycle but overwintering eggs are laid on rose.

- Apple orchards are invaded by a migration of adults to summer hosts in June.
- There is a return migration of second generation adults to rose to lay eggs in the autumn.

Pest status

Leafhoppers are minor pests of apple and pear but they have increased in abundance in apple orchards in recent years and have become troublesome in some orchards.

Other hosts

- The commonest species in apple orchards currently, *Edwardsiana crataegi*, infests fruit trees including apple, pear, cherry, damson and plum.
- Hawthorn is its main wild host but it also occurs on a wide range of other rosaceous plants.
- The second most common leafhopper, *Edwardsiana rosae*, also has a similarly wide host range including fruit trees, gooseberry, blackberry, raspberry, strawberry, hop and nut.
- The leafhopper *Alnetoidia alneti* occurs on alder windbreaks and also infests apple, cherry and plum.

Varietal susceptibility

There are considerable differences in the susceptibility of apple varieties but these have not been adequately quantified. Some of the newer desert varieties seem particularly susceptible.

Distribution

The main species, *Edwardsiana crataegi*, is widespread and abundant in apple orchards.

Damage

Leafhoppers feed on the non-vascular leaf tissue (mesophyll cells), puncturing the cells and withdrawing the sap.

- This causes white speckling of the leaves visible from above and below.
- Damage is usually most intensive on older leaves in the centre of the tree.
- When populations are very high, leaves of apple trees can become bleached by the end of the season.
- The photosynthetic activity of the tree is reduced as the chlorophyll content of cells is removed.
- This can adversely affect tree vigour and return bloom.
- Fruit surfaces below leaves which are fed on can become contaminated by numerous small brown spots of excrement.
- This contamination is fairly easily washed away by water, including by rain, during post-harvest drenching or grading.
- Some leaf hoppers transmit diseases.
- The leafhopper *Fieberiella flori* is a vector of the phytoplasma disease that causes apple proliferation disease. The vector does not occur in the UK.

Recognition

- Leafhoppers that occur on apple in the UK are small (mostly 3-5 mm long) slender insects, usually green or yellow in colour (though some species are brightly coloured), found mainly on the undersides of leaves associated with the speckling damage they cause to foliage.
- They are active insects and jump and fly readily especially in warm conditions.
- The various species that occur on fruit trees are generally similar in appearance though some have characteristic markings on their body or wings.

Adult
The commonest species are 3-4 mm long, pale yellow with a yellow abdomen.

Nymph
Nymphs are like adults but smaller and are without fully developed wings.

Monitoring

Leafhopper populations are best monitored by visual inspection for the characteristic speckling damage which occurs initially on older leaves in the centre of the tree, and for the leafhoppers themselves which are often present on the undersides of damaged leaves.

- When populations are high, brushing the foliage or shaking the tree will cause large numbers of adults to leap from the tree and make a short flight before re-settling.
- In cool conditions, leafhopper populations can be estimated by beat sampling. However, in warm conditions most individuals simply fly away and do not fall into the beating tray.
- Another approach is to use yellow or white sticky traps.
- Economic thresholds have not been developed.
- However, damage is only likely to be significant if a large proportion of the leaf surface becomes bleached in mid or late summer.

Forecasting

Useful forecasting methods have not been developed for the leafhopper pests of apple.

Chemical control

A spray of an approved insecticide should be applied in summer against adults and nymphs if leaf damage starts to become unsightly and is increasing.

- Nicotine is the only insecticide recommended by the manufacturer for control of leafhoppers on fruit trees. However, it is toxic to humans and is harmful to predatory mites and its use should be avoided. Approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.
- The commonest leafhopper species on apple appears widely resistant to chlorpyrifos (Dursban etc.) (see 'Insecticide resistance' below).
- Thiacloprid (Calypso), though only specifically recommended by the manufacturer for control of aphids, will give incidental control of leafhoppers and it is likely that other neonicotinoids such as acetamiprid (Gazelle) and thiamethoxam (Centric) are similarly effective.
- Synthetic pyrethroids are also effective but they are harmful to the orchard predatory mite *Typhlodromus pyri* and many other natural enemies and should only be

used as a last resort where no alternative can be used.

Insecticide resistance

- Resistance of the commonest leafhopper species in apple orchards in the UK, *Edwardsiana crataegi*, to organophosphorus insecticides has been demonstrated in other countries. Chlorpyrifos (Dursban) is apparently ineffective against this leafhopper in the UK suggesting that the species is also widely resistant here.

Cultural control

There are few cultural control approaches for this pest. Spatial isolation of orchards from wild alternate hosts may be beneficial, especially for species that have an obligate alternative host (e.g. Edwardsiana rosae).

- Avoiding using broad-spectrum insecticides to allow parasites and other natural enemies to flourish will help.
- However, leafhoppers are often very abundant on unsprayed apple trees.

Natural enemies

Predatory insects and spiders
Leafhoppers appear to have few natural enemies. They are preyed on by nabid bugs and spiders.

Parasitic flies and wasps
Parasitic flies and wasps are the most important natural enemies of leafhoppers.

- Pipunculid parasitic flies in the genus *Chalarus* lay their eggs singly into the abdomen of third to fifth instar leafhopper nymphs.
- The larva of the parasites have two instar stages, the second only occurring in the adult host.
- The parasite larva consumes most of the host's tissues and emerges through its skeleton. Up to 20% parasitism has been recorded.

Dryinid parasitic wasps in the genus *Aphelopus* also inject their eggs singly into the abdomen of leafhopper nymphs.

- The egg hatches when the nymphs are mature or when they reach adulthood.
- Dryinid parasitic wasps have five larval instars but only for the first two instars is the body of the parasite entirely within the host's body.
- The late second and subsequent instars are semi-external.
- The parasites head and part of its tail remain inside the host but the remainder is external and curves between the attachment points in an arc.
- The external parts contain a brown/black sack, which contains moulted skins.
- Development takes about six weeks.
- The larvae then splits the sack with the head remaining attached to the host while the parasite consumes it.
- The larva then moves away and spins a cocoon in which it pupates. *Aphelopus* species can cause up to 20% parasitism.

Another group of parasitic wasps, the mymarids known as fairy flies (*Anagrus, Anaphes, Gonatocerus* and *Polynema* species), are egg parasite and can sometimes cause high levels of parasitism.

Biological control

Biological control approaches for leafhoppers on apple have not been developed.

- Inundative releases of parasitic wasps that parasitise eggs have been use to effect to control other leafhopper species on other crops in other countries.
- However, this approach is likely to be uneconomic.

Biotechnological control

Biotechnological control measures have not been developed.

Further reading

Charles, J. G., Walker, J. T. S. & White, V. 1994. Resistance of Froggatt's apple leafhopper *Edwardsiana crataegi* Douglas, to azinphos-methyl. *Proceedings of the Forty Seventh New Zealand Plant Protection Conference*, 333-336.

Jay, C. N. & Cross, J. V. 1996. Survey of leafhopper damage to apple 1996. Report of APRC project SP106 issued 3 January 1997, 14pp.

Krczal, G. Krczal, H & Kunze, L. 1989. *Fieberiella flori* (Stal.), a vector of apple proliferation agent. *Acta Horticulturae* 235, 99-106.

MacNeil, J. D., Hikichi, M. & Downing, R. S. 1987. An investigation of the effects of seasonal changes, leaf maturity, nitrogen deficiency and leafhopper injury on the chlorophyll content and diffuse reflectance spectroscopic properties of orchard leaves. *International Journal of Environmental Analytical Chemistry* 31, 52-62.

Light brown apple moth (Epiphyas postvittana (Walker))

Light brown apple moth (a tortricid) is a minor, but sporadic pest of apple in the UK. The life cycle involves at least two generations per annum in the UK. The moth has a very wide host range and the larvae are known to feed on over 120 plant species.

It is generally controlled by sprays targeted against codling moth and other tortricid pests and in UK horticulture it more often causes damage to cherry and plum because of the limited choice of insecticides available for and used on these crops.

Larvae are leaf-rollers and damage is similar to other leaf-roller species. Damage to foliage is unimportant. Fruit generally suffers from surface damage but young larva may enter fruit through the calyx.

The identification of larvae is difficult as they are very similar to the larvae of other leaf rollers. The pest should be monitored with pheromone traps weekly from petal fall of apple to the end of August. The economic threshold for treatment is >30 moths per trap per week.

Male light brown apple moth

Control

Several insecticides are approved for control of tortricid moths and/or other caterpillars on apple and/or pear in the UK and these are also applicable to light brown apple moth. Light brown apple moth is, fortuitously, controlled by several of the sprays targeted against codling moth and fruit tree tortrix moth.

As light brown apple moth is a comparatively new pest to Britain we have only limited experience in controlling it with insecticides and comprehensive efficacy trials have not been done on apple.

- However, experience has shown that chlorpyrifos (various products), indoxacarb (Steward) and methoxyfenozide (Runner) are effective.
- On cherry, *Bacillus thuringiensis* (Dipel) and surprisingly cypermethrin (various products) have given disappointing results.
- Spray programmes applied for control of codling and tortrix moths on apple are likely to give good incidental control of light brown apple moth. However, special control measures may be required if damaging populations of the pest develop.
- Sprays should be timed according to sex pheromone trap catches. Larvicides should be applied 7-10 days after a threshold catch of 30 moths per trap is reached, with sprays repeated at fortnightly intervals to give protection through the egg hatch period.
- For details on how to use the various available insecticides, see fruit tree tortrix moth.

Female light brown apple moth

Light brown apple moth larvae

Webbing and surface grazing to leaf by light brown apple moth

Insecticides approved for control of codling, tortrix moths (light brown apple moth) or caterpillars on apple and pear

Choice of insecticides - efficacy factors

Active ingredient	Trade name	Class[1]	Selectivity	Label rec's[2]	Safety to *Typhs*	Suggested interval between sprays (days)
Bacillus thuringiensis	Dipel	bacterial insecticide	selective to caterpillars	c (SOLA)	safe	3-14
bifenthrin	brigade	pyrethroid	broad-spectrum	Red spider mite	harmful	14-21
chlorpyrifos	Dursban, etc.	OP	broad spectrum	c, cm, t	safe	14-21
cypermethrin	various	pyrethroid	broad spectrum	c, cm, t	harmful	14-21
deltamethrin	Decis	pyrethroid	broad spectrum	cm, t	harmful	21
diflubenzuron	Dimilin	CSI	selective	c, cm, ftt	safe	28
indoxacarb	Steward	oxadiazine	selective	c, cm, ftt,	u	10-14

				sft		
fenoxycarb	Insegar	JHA	selective	sft	safe	21
methoxyfenozide	Runner	MAC	selective	c	safe	u
nicotine*	various	alkaloid	broad spectrum	c	harmful	7
spinosad	Tracer	neural blocker	selective	C, cm, ftt,sft	safe	10

Choice of insecticides - Safety factor

Read and follow the label before applying any sprays

	Hazards[2]				**Harvest interval (days)**	**Max. no. sprays**	**Buffer zone Width (m)**
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
Bacillus thuringiensis	no	u	u	u	0	u	u
bifenthrin	no	h,i	ed	ed	u	2	30
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
diflubenzuron	no	u	u	u	14	3	u
indoxacarb	no	h	ed	u	7	3	15
fenoxycarb	no	u	d	d	42	2	18
methoxyfenozide	no	u	u	u	14	3	5
nicotine*	no	t, h	d	h	2	u	u
spinosad	no	u	ed	u	7	4	40

Keys: [1]OP=organophosphate, CSI=chitin synthesis inhibitor, JHA=juvenile hormone analogue

[2]c=caterpillars, ftt=fruit tree tortrix, sft=summer fruit tortrix, t=tortrix

[3]d=dangerous, ed=extremely dangerous, h=harmful, i=irritant, t=toxic, u=no hazard specified

* approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Control in organic orchards

Light brown apple moth has the potential to cause significant fruit damage in organic orchards.

- If control measures are necessary, sprays of the biological control agent *Bacillus thuringiensis* (Dipel) should be applied although this has given disappointing results in trials on cherries.
- Spinosad (Tracer) offers a good alternative, (see 'Chemical control' above)
- Also consider cultural control measures.

Further reading

Life cycle

- There are at least two generations per annum in the UK.
- Larval development has 5-6 instar stages.
- Adults can fly between February and Dec, although April to October is more usual.
- The first generation larvae occur on fruit and leaves in June-July and the second generation larvae over-winter, probably in leaf litter.
- It is expected that more generations will occur in the UK with climate change.
- The first generation of moths emerge at the beginning of April from over-wintered larvae and the second generation at the end of July.
- Eggs are laid in batches on the foliage. These hatch in 2-3 weeks depending on temperature (see 'Monitoring and Forecasting').
- Larvae pupate when fully fed, normally in early May and early June.
- Cool and wet weather conditions at the time of moth flight and/or during egg-hatch limit population increase.
- The tiny first instar larvae spin webs of silk, usually on the undersides of leaves, often at a junction between the main and a side vein, and begin to feed.
- Later they may feed on the surface of the fruits or in the calyx cavities of fruits.
- Normally, the rate of larval development is slowed considerably during the winter; thus the majority of larvae over-winter in the prolonged early juvenile phases of the second, third, and fourth instars.
- During this period they normally feed on herbaceous plants. Re-invasion of apple trees takes place from the beginning of April.

Pest status

Increasing pest of apple and pear and several other fruit crops. Attacks foliage and fruit.

Other hosts

Highly polyphagous, the larvae feed on a wide range of trees and shrubs including fruit trees and bushes.

Varietal susceptibility

All varieties are susceptible, but those with fruits that are short stalked and/or which hang in clusters, will suffer the most damage.

Distribution

Common and widely distributed.

Damage

Larvae are leaf-rollers and damage is similar to other leaf-roller species. Damage to foliage is unimportant. Damage to fruits occurs at different times during fruit development.

- Early instars often settle on the under surface of leaves close to the main veins, where they construct silken shelters and feed on the leaf tissue sometimes creating small windows in the leaves.
- Larvae can be found on shoot tips or areas of new growth, where they web the leaves together with silk.
- A third settlement site is the calyx, where their presence is detected only from observing the fine silken webbing among the sepals.
- Later larval stages construct feeding niches between adjacent leaves and/or fruit, in the developing bud, or on a single leaf (leaf rolling).
- Fruit suffers from surface damage, particulary in compact cluster varieties.
- Internal damage to fruit is less common, but a young larva may enter fruit through the calyx. Excreta are usually ejected on to the outside of the fruit; this does not happen with the codling moth.

Recognition

Adult (resting)

- In the adults the forewing is characteristically curved.
- Male moths are 6-10 mm long, with the front part of the forewing generally much lighter than the back, which is rusty dark red/brown.
- Much lighter forms may also be found.
- The females are generally larger than the males (7-13 mm long) and are more difficult to identify as colour varies from a uniform light yellowish brown with almost no distinguishing marks.
- However, females do have a small dark spot over the centre of the body, on the forewings, visible when at rest .

Egg

- Usually on the upper surface of plant leaves in batches of 2 - 170.
- They are flat with a pebbled surface.

- They overlap each other within the raft to form a smooth mass.
- Approximately 0.7 mm by 1.0 mm, they are initially white to pale green and change to a paler yellow green as they develop.

Larvae

The identification of larvae is problematic as they are very similar to the larvae of other leaf rollers.

- The first larval instar [stage] has a dark brown head; all other instars have a light fawn head and prothoracic plate [plate behind the head].
- Over-wintering larvae are darker.
- First instar larvae are approximately 1.6 mm long, and final instar larvae range from 10 to 18 mm in length.
- The body of a mature larva is medium green with a darker green central stripe and two side stripes.
- The last body segment breathing pores (spiracles) are larger than rest.
- They spin fine webbing and often occur in leaf rolls or beneath a leaf tied to fruit.

Other pests with which light brown apple moth may be confused

- Larvae of several leaf-rolling tortrix moths are very similar and are difficult to distinguish from each other.
- Larvae of the summer fruit tortrix moth and fruit tree tortrix moth, occur commonly in orchards in the UK, especially in the south and east, and are particularly difficult to distinguish from those of the light brown apple moth.

Monitoring

Pheromone traps

The flight activity of male moths (along with that of the codling moth, summer fruit tortrix moth and fruit tree tortrix) should be monitored using sex pheromone traps (a different trap is used for each species). The delta design is used widely.

- Traps should be set out in orchards shortly after blossom.
- Each orchard should be individually monitored with a trap. The traps should be hung from the branch of a tree at mid canopy height in the centre of the orchard and oriented to allow flow through of the prevailing wind.
- The number of moths should be recorded weekly, and captured moths removed.
- Lures should be changed every 6 weeks as recommended by the manufacturer. Sticky bases should be changed if their effectiveness declines.
- The economic threshold is considered to be 30 moths per trap per week, though this may be a conservative estimate.
- Temperature sums to predict egg hatch to determine correct timing of egg hatch sprays should be started from the date when the first threshold catch is recorded.

Caterpillar damage

- Inspect leaves for evidence of leaf roller activity in May-June.

Fruit damage

- Inspect fruits for damage, either whilst developing on the tree, at harvest or during grading (remembering that badly damaged fruit may have been discarded at harvest)'
- This indicates if populations have been high and whether treatment is likely to be required for the next generation or the next season.

Forecasting

The rate of development of each of the development stages of light brown apple moth is only completed when a known heat sum has accumulated.

- Heat sums can be calculated each day from the daily maximum and minimum air temperature.
- PESTMAN can be used to give approximate predictions of the timing of occurrence of each of the life stages of the pest.

Chemical control

Several insecticides are approved for control of codling, tortrix moths (light brown apple moth is a tortricid)) or caterpillars on apple and pear. As light brown apple moth is a comparatively new pest to Britain we have only limited experience in controlling it with insecticides and comprehensive efficacy trials have not been done.

- However, experience has shown that chlorpyrifos (various products), indoxacarb (Steward) and methoxyfenozide (Runner) are effective.
- On cherry, *Bacillus thuringiensis* (Dipel) and surprisingly cypermethrin (various products) have given disappointing results.
- Spray programmes applied for control of codling and tortrix moths on apple are likely to give good incidental control of light brown apple moth.
- However, special control measures may be required if damaging populations of the pest develop.
- Sprays should be timed according to sex pheromone trap catches.
- Larvicides should be applied 7-10 days after a threshold catch of 30 moths per trap is reached, with sprays repeated at fortnightly intervals to give protection through the egg hatch period.
- For details on how to use the various available insecticides, see Fruit tree tortrix moth.

Insecticide resistance

- *Bacillus thuringiensis* (Bt) has been used to control light brown apple moth although some populations have become resistant and there is some evidence of avoidance of Bt contaminated food by the larvae.
- In Australia and New Zealand, light brown apple moth has developed resistance to organophosphate and carbamate pesticides, including chlorpyrifos but no resistance to pyrethroids has been observed.

Biological control

A programme of weekly sprays of *Bacillus thuringiensis* (Bt) (Dipel DF) throughout the egg hatch period gives fairly good control but is costly compared to other insecticides.

- Bt has to be ingested to act and is most effective in warm weather when caterpillars are feeding actively.
- The bacterium produces a crystalline toxin. The insect dies from the effects of this toxin rather than from pathogenesis due to the bacterium.
- Bt is of short persistence as it is degraded by heat and UV light.
- It is most effective against newly hatched larvae before they form leaf rolls in which they feed internally and are inaccessible to sprays.
- The first spray should be applied at the onset of egg hatch which should be determined from pheromone trap catches and egg development sums calculated from the daily maximum and minimum air temperature (see 'Monitoring and Forecasting').

- Bt is not detected by conventional pesticide residue analysis.
- See also 'Chemical control and Insecticide resistance'.

Natural enemies

The light brown moth has many natural enemies. Parasitic wasps especially reduce populations to comparatively low levels in unsprayed orchards but parasites are less abundant in orchards sprayed with broad-spectrum insecticides. Light brown apple moth larvae and pupae are killed by various parasitoids, predators, and diseases. Spiders and earwigs (*Forficula auricularia*) are the most important predators. Although much is known about the parasitoids of light brown apple moth in Australia and New Zealand, less is know about the effect on light brown apple moth population in the UK.

Insectivorous birds

- As with other tortricids, birds probably pay a contributing role in controlling numbers of light brown apple moth, but birds do not forage specifically for the pest unless population densities are very high and for this reason are of limited value only.

Egg parasites

- Parasitic wasps (*Trichogramma* sp.) attack the eggs but parasitism rates are generally low.

Larval and pupal parasites

- Several parasitic wasps and flies parasitise light brown apple moth larvae or pupae, but these are unlikely to have a significant controlling effect.

Predatory insects

- Earwigs and predatory mirid and anthocorid bugs feed on eggs and young larvae.

Virus diseases

- Infection by a nuclear polyhedrosis virus has been known to decimate localised light brown apple moth populations.

Biotechnological control

Mating disruption systems for light brown apple moth in apple orchards are used in Australia, New Zealand and the USA and are effective, providing initial moth populations are low.

Cultural control

Trees which have a dense canopy and vigorous shoot growth tend to support greater populations of caterpillars.

- If shoot growth then ceases when caterpillars are young due to water stress and/or a heavy fruit load, the caterpillars tend to move to feed on fruits, especially those in clusters, and damage intensifies.
- Avoiding this situation by tree management reduced losses.
- Furnishing the trees with artificial refuges for earwigs and other insect predators (see Rosy apple aphid) is likely to help reduce young caterpillar populations.

Further reading

Bradley, S. J., Walker, J. T. S., Wearing, C. H., Shaw, P. W. and Hodson, A. J. 1998. The use of pheromone traps for leafroller action thresholds in pipfruit. *Proceedings of the 51st N.Z. Plant Protection Conference, 173-178.*

Van der Geest, L. P. S. & Evenhuis, H. H. (Eds). 1991. *Tortricid Pests, Their Biology, Natural Enemies and Control* . World Crop Pests, Vol. 5. Elsevier, Amsterdam.

Mussel scale (Lepidosaphes ulmi (Linnaeus)) and other scale insect pests

Mussel scale has become an increasingly important and common pest of apple in recent years. It sometimes attacks pear.

Several other scale insects including pear scale, oyster scale and nut scale also occur locally, mainly on cider apples which are infrequently sprayed with insecticides. Mussel scale is readily distinguished from the others as it is the only one that is mussel-shaped whereas pear scale and oyster scale are roughly circular.

Wild hosts such as hawthorn may act as a source of infestation.

The main damage is caused by the presence of mussel scales on the surface of fruits at harvest. The contamination is superficial but may downgrade the fruit.

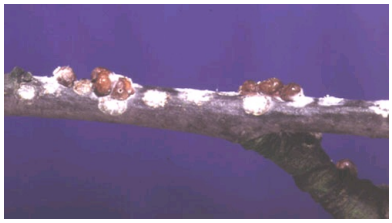
Very heavy infestations on the bark may debilitate the tree and there may be some contamination of the foliage with honeydew.

The life cycle is limited to one generation per year. The timing of egg hatch and dispersal on the tree varies between years depending on spring temperatures.

Correct timing of insecticide sprays for control is important and should be determined by regular monitoring.

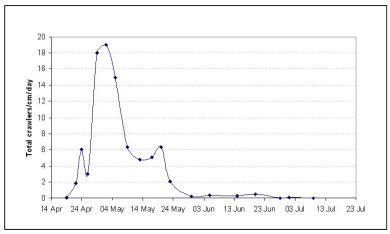
- Weekly examination of mother scales and the surface of the bark on dry days though the critical period is required.
- Alternatively, the branches of infested trees may be furnished with sticky bands made from double sided sticky tape and the numbers of crawlers captured counted and the bands refreshed each week.
- By this method it is possible to ascertain when approximately 80-90% of scales have emerged.
- This is the critical time for application of first sprays. A temperature-based forecasting model can give useful back-up.

Mussel scale infested fruit

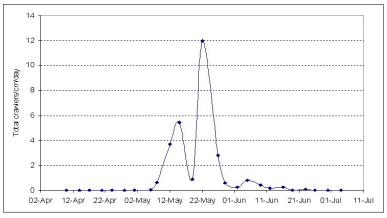


Nut scale on Bramley branch

Control



Mussel scale crawler emergence in 2007: Numbers of crawlers captured in sticky bands in a Kent Cox orchard



Mussel scale crawler emergence in 2008: Numbers of crawlers captured in sticky bands in a Kent Cox orchard

- This is best achieved with one or more sprays of thiacloprid (Calypso) or acetamiprid (Gazelle) in late May- early June, timed to coincide with the latter stages of crawler mergence.
- If a single spray of one of these materials is to be used against light infestations, it is best applied at about 80-90% crawler emergence.
- These insecticides are most effective against emerged migrating crawlers and first and second stage scales that have recently settled at their feeding sites. They have little effect on scales that have not emerged from under their mother scale.
- As the insecticides only have effective action for a week or two, applications in the later stages of the emergence cycle catch the maximum proportion of the population at the susceptible stage.
- Trials results show that addition of a silicone adjuvant improves efficacy but care should be taken to avoid possible phytotoxic damage to fruits, especially in hot conditions at the time of, or during the days following, spraying.
- Where heavy infestations occur (significant damage the previous year or high numbers of scales in the previous seasons shoots) a second application should be made 10-14 days later, possibly bringing the first spray forward nearer to 50% emergence.
- Where infestations are really heavy, 3 applications may be required, remembering not to exceed the maximum permitted for any one product.
- Spirodiclofen (Envidor) also has significant activity against mussel scale but takes one to two weeks to act so it probably has to be applied earlier in the emergence period to get maximum effect. It appears to give better control of scale insects on the bark than it does of those on the fruitlets, so maximum benefits of treatment with this insecticide may not be apparent till the following year.
- Fatty acids (Savona) is the only insecticide recommended by the manufacturer currently for control of scale insects on fruit trees during the growing season. If this material is used, high volume sprays are necessary to thoroughly wet the wood, timed to control the crawlers. However, such treatment is likely to be very costly.
- Sprays of other broad-spectrum insecticides such as chlorpyrifos (various products) applied at medium to high volume at this time are also likely to be partially effective.
- Synthetic pyrethroids are also partially effective but they should not be used because they are harmful to the orchard predatory mite *Typhlodromus pyri* and many other important natural enemies.
- Note that fenoxycarb (Insegar) was ineffective in HDC-funded trials in 2007 and 2008.

Insecticides approved for use on apple and pear which are recommended for or may give control of scale insects

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of -	Safety to *Typhs*
acetamiprid	Gazelle	neonicotinoid	broad-spectrum, systemic	Aphids and Whitefly	safe
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars, sawfly, capsids etc.	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
fatty acids	Savona	soap	broad spectrum	Aphids, scale insects	harmful
spirodiclofen	Envidor	ketoenol insecticide and acaricide	partially selective	Spider mites, rust mites, pear sucker and mussel scale on apple and pear	harmful

thiacloprid	Calypso	chloro-nicotinyl	broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids and sawfly, though not caterpillars or woolly aphid)	safe
thiamethoxam	Centric	Neonicotinoid	broad-spectrum, systemic	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe

Choice of insecticides - Safety factors

Read and follow label before applying sprays

	Hazards				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)	
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees				
acetamirpid	no	u	h	u	14	2	20	
chlorpyrifos	yes	h, i	ed	ed	14	3	18	
cypermethrin	no	h, i	ed	d	0	5	18	
deltamethrin	no	h, i	ed	d	0	u	18	
fatty acids	no	u	h	u	0	u	sm	
spirodiclofen	no	h	h	d	14	1	30	
thiacloprid	no	h, i	h	h	14	2	30	
thiamethoxam	no	h	h	d	14	2	sm	

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, c=closed cab required for air assisted sprayers, u=uncategorised/unclassified/unspecified

Control in organic orchards

- Priority should be given to cultural control methods and fostering natural enemies.
- High volume sprays of fatty acids (Savona) may be used as described under 'Chemical control' above. The importance of correct timing of sprays is stressed.

Further reading

Life cycle

Mussel scale has one generation per year. Eggs are laid in the autumn and are deposited by the female under the scale shell before she dies.

- Eggs hatch in late May or early June and the first stage nymphs, known as crawlers, disperse over the tree during a period of approximately 4-6 weeks, though small numbers continue to emerge for several more weeks.
- The timing of migration varies between years depending on spring temperatures.
- When they have found a suitable feeding site, they settle mainly on the bark but also on fruitlets where they remain for the rest of their life.
- Each then moults to a second instar and then a third instar nymph, both stages being sedentary remaining in the same place and protected by the mussel-shaped scale formed from wax and the cast nymphal skin.

- In late August and September, each female deposits up to 80 eggs beneath the scale, then dies.
- The scale remains attached to the bark and protects the eggs through the winter.
- Although males appear in some races of mussel scale, only females occur on fruit crops and reproduction is entirely parthenogenetic.

Pest status

Mussel scale

- A minor but common pest of apple and sometimes pear.

Other scale insects

- Oyster scales, pear scale and nut scale are also minor pests of fruit trees in the UK but occur less frequently than mussel scale.
- The San José scale is a destructive and widespread pest of fruit trees but has not yet been recorded in Britain.

Other hosts

Mussel scale

- Occurs on many other woody host plants. Fruit crop hosts include apple, pear, cherry, plum, bilberry and less frequently currant and gooseberry.
- Other hosts include blackthorn, cotoneaster, hawthorn, heath, heather and many others.
- Populations on hawthorn, heather and other wild plants are believed to be the main sources of infestation of orchards.

Other scale insects

- In the UK, oyster scale occurs on apple, apricot, birch, cherry, currant, nectarine, peach, pear and plum. Birch is considered to be the original host.
- Pear scale occurs on apple, peach, pear and poplar.
- Nut scale occurs on apple, pear and plum

Varietal susceptibility

All the commonly grown apple varieties are susceptible to mussel scale.

Distribution

Widespread and common. Low levels of infestation occur in many orchards.

Recognition

Adults
2.0-3.5 mm long, flat and mussel–shaped, grey to yellowish brown. Found on the bark and fruits of apple trees.

Nymphs (crawlers)
Oval, pale yellowish brown.

Eggs
Minute, oval and white. Deposited beneath the scale.

Other pests with which mussel scale may be confused

- Only mussel scale is mussel-shaped.
- Pear scale and oyster scale individuals sometimes settle on fruits mainly round the calyx, but are roughly circular.

Damage

- The main damage is caused by the presence of mussel scales on the surface of fruits at harvest.
- The contamination is superficial but may downgrade the fruit.
- Very heavy infestations on the bark may debilitate the tree and there may be some contamination of the foliage with honeydew.
- At first, the upper surface of the leaves assumes a glistening, sticky appearance but it later becomes unsightly with the growth of sooty mould fungi on the honeydew.

Monitoring

Visual inspection

- Record the percentage of fruits at harvest contaminated by mussel scale.
- If the level is economically significant (e.g. >1%), then insecticidal treatment may be justified in the dormant period or after blossom the following year.
- The bark of apple trees should be examined in the dormant period (early on if a tar oil winter wash treatment is to be applied) for signs of infestation.

Monitoring crawler emergence

- Correct timing of insecticide sprays for control is important and should be determined by regular monitoring.
- Weekly examination of mother scales and the surface of the bark on dry days though the critical period is required.
- Alternatively, the branches of infested trees may be furnished with sticky bands made from double sided clear sticky tape (see image) and the numbers of crawlers captured counted.
- The bands should be refreshed each week.
- By this method it is possible to ascertain when approximately 80-90% of scales have emerged, the critical time for application of first sprays.

Forecasting

A mass hatch of the eggs of mussel scale often occurs in a short time period of a few days in late May or June.

- Insecticide sprays need to be targeted against the young crawlers that emerge.
- Mature larvae are protected by their outer scale and are much less susceptible to insecticides.
- For this reason, pinpointing the timing of the mass hatch is helpful to time sprays correctly.
- The timing of the hatch and the optimum timing for application of sprays can be predicted from

temperature sums.

- First emergence occurs at 151 day-degrees above a threshold of 8ºC after 1 January.
- Mass egg hatch occurs at about 190 day-degrees. 90% hatch occurs at 230 day-degrees and is considered to be the optimum timing for application of commonly used pesticides.
- Early hatched nymphs may reach the second instar stage by this time but these are still susceptible to the commonly used insecticides.

Sticky band trap round trunk of tree to monitor numbers of migrating mussel scale crawlers, which can be seen in large numbers.

Chemical control

Correct timing of insecticide sprays for control is important and should be determined by regular monitoring (see 'Monitoring'). It is a common error that sprays are applied too early. Eggs in shaded places hatch well after those exposed to the sun.

- Control is best achieved with one or more sprays of thiacloprid (Calypso) or acetamiprid (Gazelle) in late May -early June, timed to coincide with the latter stages of crawler mergence.
- If a single spray of one of these materials is to be used against light infestations, it is best applied at about 80-90% crawler emergence.
- These insecticides are most effective against emerged migrating crawlers and first and second stage scales that have recently settled at their feeding sites. They have little effect on scales that have not emerged from under their mother scale.
- As the insecticides only have effective action for a week or two, then applications in the later stages of the emergence cycle catch the maximum proportion of the population at the susceptible stage.
- Trials results show that addition of a silicone adjuvant improves efficacy but care should be taken to avoid possible phytotoxic damage to fruits, especially in hot conditions at the time, or during the days following, spraying.
- Where heavy infestations occur (significant damage the previous year or high numbers of scales in the previous seasons shoots) a second application should be made 10-14 days later, possibly bringing the first spray forward nearer to 50% emergence and where infestations are really heavy, 3 applications may be required, remembering not to exceed the maximum permitted for any one product.
- Spirodiclofen (Envidor) also has significant activity against mussel scale but takes one to two weeks to act so it probably has to be applied earlier in the emergence period to get maximum effect.
- It appears to give better control of scale insects on the bark than it does of those on the fruitlets, so maximum benefits of treatment with this insecticide may not be apparent till the following year.
- Fatty acids (Savona) is the only insecticide recommended by the manufacturer currently for control of scale insects on fruit trees during the growing season.
- If this material is used, high volume sprays are necessary to thoroughly wet the wood, timed to control the crawlers. However, such treatment is likely to be very costly.
- Sprays of other broad-spectrum insecticides such as chlorpyrifos (various products) applied at medium to high volume at this time are also likely to be partially effective.
- Synthetic pyrethoids are also partially effective but they should not be used because they are harmful to the orchard predatory mite *Typhlodromus pyri* and many other important natural enemies.
- Note that fenoxycarb (Insegar) was ineffective in HDC-funded trials in 2007 and 2008. Medium to high volume spraying to obtain good cover is likely to give better results.
- In other European countries, white oil sprays are used at mouse ear stage, giving a fairly good control. There is no approval for such treatment in the UK.

Insecticide resistance

Insecticide resistance is not known to occur in mussel scale populations.

Cultural control

- There are few obvious cultural control measures for this pest.
- Isolation from hawthorn and other trees that are wild hosts will reduce the probability of infestation developing.
- Mussel scale populations tend to be greatest in old orchards where the pest has been allowed to increase without check over a number of seasons.
- Physical destruction of colonies or their removal may be possible but is unlikely to be economic.

Natural enemies

Scale insect populations are host to a complex of natural enemies.

Parasitic wasps

The minute chalcid wasp *Aphytis mytilaspidis* is a common external parasite of mussel, oyster and pear scales.

- The egg of the parasite, usually one per scale, is laid under the waxy scale, close to the body of the insect.
- The wasp has two generations per year and can feed on the second nymphal stage as well as on the adult female.
- The greatest extent of parasitism of mussel scale recorded is 26%, but in most cases parasitism is much lower.

Several other species of parasitic wasp also attack mussel and other scale insects.

- Levels of parasitism can be assessed by looking for small circular holes in the old scales from which the adult wasps have emerged.
- However, natural populations of the parasitic wasps do not constitute a significant or reliable regulatory mechanism.

Predatory insects

- Ladybird adults and larvae, mirid and anthocorid bugs, earwigs and predatory mites often destroy large numbers of scales, particularly the vulnerable young stages.

Biological control

Biological control of mussel scale has not been developed.

- However, the parasitic wasp *Encarsia perniciosi* has been introduced to control the San José scale with some success in other European countries.

Further reading

Ben-Dov, Y. & Hodgson, C. J. 1997. World Crop Pests, Volume 7B. Soft Scale Insects – Their Biology, Natural Enemies and Control. Amsterdam, Elsevier.

Helsen, H. H. M., Blommers, L. H. M. & Trapman, M. C. 1996. Timing observation and control of mussel scale *Lepidosaphes ulmi*. *IOBC wprs Bulletin* 19(4), 145-149.

Kosztarab, M. & Kozar, F. 1988. *Scale insects of central Europe*. Akademiai Kiado, Budapest, 456 ppRosen, D. 1990. World Crop Pests, Volume 4B. Armored Scale Insects – Their Biology, Natural Enemies and Control. Amsterdam, Elsevier.

Rhynchites weevil (Rhynchites aequatus (Linnaeus))

The apple fruit rhynchites is a local but destructive pest of apples which has been increasing in importance in recent years so monitoring is advisable. Hawthorn is the normal host but apple and occasionally pear, plum and cherry can be attacked.

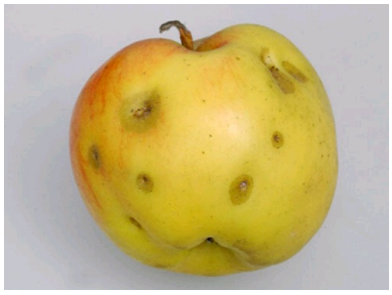
Adult Rhynchites weevil

Adults are readily recognised being reddish-brown and having a typical long weevil snout. During blossom and early fruitlet development, the adult weevils drill small cylindrical holes into the flesh with their rostrum. Numerous holes may be made in one fruitlet, or in a group of adjacent fruitlets, by a single weevil. Feeding can continue till July.

At the base of some holes, single eggs may be laid. These hatch after a week or so and the larva feeds on the surrounding flesh, becoming fully grown in about 3 weeks. They then drop to the ground and eventually pupate in the soil, each within an earthen cell. There is apparently one generation per annum.

Fruitlet damage can be serious and is very characteristic. On apple there may exceptionally be 100 or more holes in a single fruitlet but more likely several or many neighbouring fruitlets will each have a small number of holes, each damaged fruit potentially being down graded.

Attacked apples remain marked and distorted, although the holes tend to close up as the fruitlets grow.



Fruitlet showing characteristic feeding damage caused by an adult apple fruit Rhynchites weevil

Control

- Experience has shown that a spray of thiacloprid (Calypso) at late blossom or early fruitlet gives good control of adults and prevents further damage.
- It is probable that other insecticides are also effective but the efficacy of different products has not been explored.
- Sprays of other broad-spectum insecticides that control adult weevils (e.g. chlorpyrifos or synthetic pyrethroids) are likely also to be effective if applied at this time.
- Use of synthetic pyrethroid insecticides should be avoided as they are harmful to the orchard predatory mite *Typhlodromus pyri* and other natural enemies.
- If effective control measures are not applied, the apple fruit rhynchites weevil can build up to high levels and cause serious damage (> 50% fruits infested).
- It can be very destructive in organic orchards where the only effective control measure is likely to be a spray of pyrethrum.

Insecticides approved for use on apple that are likely to control apple fruit rhynchites weevil adults. No products have a specific label recommendation for the pest.

Choice of insecticides - efficacy factors

Active ingredient	Trade names	Class[1]	Recommended by the manufacturer for control of -	Safety to *Typhs*
bifenthrin	pyrethroid	broad-spectrum	Red spider mite	harmful
chlorpyrifos	Various products.	OP	Apple blossom weevil on apple and pear, aphids, caterpillars, capsids, suckers, codling and tortrix moths, saw flies	safe
cypermethrin	Various products	pyrethroid	Aphids, suckers, capsids, caterpillars, codling and tortrix moths	harmful
deltamethrin	Decis etc.	pyrethroid	Aphids, suckers, capsids, caterpillars, codling and tortrix moths	harmful
thiacloprid	Calypso	chloronicotinoid	aphids	safe
thiamethoxam	Centric	neonicotinoid	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe

Choice of insecticides - Safety factors

	Hazards[2]				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
bifenthrin	no	h,i	ed	ed	u	2	30
chlorpyrifos	yes	h,i	ed	d	14	3	18
cypermethrin	no	h,i	ed	d	0	5	18
deltamethrin	no	h,i	ed	d	0	-	18
thiacloprid	no	h, i	h	h	14	2	30
thiamethoxam	no	h	h	d	14	2	sm

Keys: [1]OP=organophosphorus insecticide

[2]d=dangerous, ed=extremely dangerous, h=harmful, i=irritant

Control in organic orchards

If effective control measures are not applied, the apple fruit rhynchites weevil can build up to high levels and cause serious damage (> 50% fruits infested).

- It can be very destructive in organic orchards where the only cultural control measure is to manage alternative hosts. However, it seems that although infestations are often associated with adjacent hawthorn, this is not always the case.
- It is probable that apple fruit rhynchites weevils may be controlled in organic orchards by a one or more sprays of pyrethrum targeted against adults after blossom

Pest status

The apple fruit rhynchites weevil is a local but destructive pest of apples which has been increasing in importance in recent years.

Other hosts

Hawthorn is the normal host but apple and occasionally pear, plum and cherry can be attacked.

Varietal susceptibility

Many commonly grown apple varieties are susceptible. The scab resistant apple variety Saturn is highly susceptible.

Distribution

- It is widespread and though local in apple orchards is normally associated with hawthorn. The pest is more common in organic orchards and orchards that do not receive regular insecticide treatments at or after blossom

Recognition

Adult
2.5-4.5 mm long; wing cases (elytra) reddish brown and hairy; head and thorax darker, strongly punctured and with a purplish to bronzy sheen.

Larva
Up to 4 mm long; whitish, with the brownish head retracted into the swollen prothoracic region.

Egg
0.7x0.5 mm; whitish and translucent.

Other pests with which apple sawfly may be confused

Apple blossom weevil (Anthonomus pomorum)
The adult apple blossom weevil is a small beetle, 3.5-6.0 mm long, with a long snout, dark brown to black, covered with brown, greyish and whitish hairs and mottled, with a V-shaped mark across the elytra and a prominent whitish spot between the elytra and thorax.

- It does not have the chestnut red colouring of apple fruit rhynchites.
- It tends to occur earlier in the year though adults can persist through blossom and the new generation of adults emerges in mid-summer.

Apple bud weevil (Anthonomus piri)
The adult of the apple bud weevil is very similar in appearance to the adult apple blossom weevil, but is a lighter, brown colour, and lays its eggs in the autumn and early spring.

- The apple bud weevil is local and rare in the UK and until recently was only recorded on apple though a recent local outbreak has occurred on pear in north Kent.
- It is an important pest of pear in continental Europe.
- The larva infests buds which are hollowed out remaining as dead husks in which the larva is found.

Apple twig cutter (Rhynchites caeruleus)

- A locally common weevil that occurs on apple but the adult is metallic blue in colour and appears much later in May and June causing characteristic shoot severing damage.

Damage

- During blossom and early fruitlet development, the adult weevils drill small cylindrical holes into the flesh with their rostrum.
- Numerous holes may be made in one fruitlet or in a group of adjacent fruitlets by a single weevil. Feeding can continue till July.
- At the base of some holes, single eggs may be laid.
- These hatch after a week or so and the larva feeds on the surrounding flesh, becoming fully grown in about 3 weeks.
- Fruitlet damage can be serious and is very characteristic.
- On apple there may exceptionally be 100 or more holes in a single fruitlet but more likely several or many neighbouring fruitlets will each have a small number of holes, each damaged fruit potentially being down graded.
- Attacked apples remain marked and distorted, although the holes tend to close up as the fruitlets grow.

Monitoring

Adults

- Adults can be seen feeding on fruitlets during and after blossom and are readily collected by beating.
- Attention should be focussed on trees near to hawthorn or where damage to fruitlets occurred the previous year.

Damage to fruits during the growing season, at harvest or during grading

- Damage occurs gradually as weevils feed over a period of weeks during and following flowering.
- Fruitlets can be readily inspected for damage.
- If significant fruit puncturing damage to fruits is seen one season, treatment the next season to avoid damage intensifying is likely to be justified.

Forecasting

No forecasting methods have been developed for this pest.

Chemical control

- Experience has shown that a spray of thiacloprid (Calypso) at late blossom or early fruitlet gives good control of adults and prevents further damage.
- It is probable that other insecticides are also effective but the efficacy of different products has not been explored.
- Sprays of other broad-spectrum insecticides that control adult weevils (e.g. chlorpyrifos or synthetic pyrethroids) are likely also to be effective if applied at this time.
- Use of synthetic pyrethroid insecticides should be avoided as they are harmful to the orchard predatory mite *Typhlodromus pyri* and other natural enemies.

Insecticide resistance

Resistance of apple fruit rhynchites weevil to insecticides is not known and is unlikely to occur.

Cultural control

- Trees could be carefully searched and adults removed and destroyed after blossom but this would be labour intensive.
- Hawthorn is the main host but the weevils are only able to complete their development on trees/hedges that flower and bear haws.

Natural enemies

Around the world several organisms are know to attack various *Rhynchities* spp.

- In the USA, *Rhynchities* spp. larvae are parasitized by ichneumonid wasps of the genus *temelucha*.
- In laboratory studies it has been possible to infect *Rhynchities* spp larvae with the nematode *Steinenernema feltiae*.
- The larvae died within 3 days.

Both trichogrammatid and braconids have been reared from the eggs of *Rhynchites* spp.

- Parasitized eggs change in appearance, the chorion becoming opaque, yellowish, thickened and wrinkled.
- The existence of these parasitoids of Rhynchites spp. provides potential biological control agents.

However, as there is a lack of biological and ecological information on these parasitic species and how to exploit them, it may be difficult to apply them in a practical situation.

Rosy apple aphid (Dysaphis plantaginea (Passerini))

Rosy apple aphid, also known as 'blue bug', is one of the most important and damaging pests of apple. A similar

Rosy apple aphid, also known as 'blue bug', is one of the most important and damaging pests of apple. A similar species, the pear bedstraw aphid, attacks pear. The life cycle involves migration between the two hosts apple and plantain.

All commercially-grown apple varieties are susceptible, but Bramley, Discovery, Egremont Russet, Golden Delicious and Jonagold are highly susceptible.

Apple orchards should be carefully inspected for the pest and its characteristic damage symptoms (discoloured/distorted/curled outer rosette leaves at the green cluster to pink bud growth stage and again at the end of blossom and during early fruitlet development. The pest can readily be distinguished from the less common rosy leaf curling aphid which causes striking red leaf curling.

Cultural controls such as encouraging natural enemies are useful. Providing refuges and flowering plants in and around the orchard, tolerating less damaging aphid species such as apple grass aphid and avoiding the use of broad-spectrum insecticides will help foster natural enemy populations in the summer and autumn so reducing populations in the current and following seasons.

Rosy apple aphid: shoot damage

Rosy apple aphid colony

Rosy apple aphid: fruit damage

Rosy leaf curling aphid damage

Control

A spray of an approved aphicide should be applied as soon as infestation is detected.

- If only rosy apple aphid is to be controlled, then pirimicarb (Aphox etc) or flonicamid (Mainman, Teppeki) are likely to be a good choice as they are selective aphicides.
- Pirimicarb (Aphox etc) in particular has to be applied in warm conditions to get good results and preferably at higher spray volumes.
- The neonicotinoids acetamiprid (Gazelle), thiacloprid (Calypso) and thiamethoxam (Centric) are also effective against rosy apple aphid and will control a range of other pests depending on the material chosen.
- Acetamiprid (Gazelle) is the most selective of these materials. Although its activity against other apple pests has not been explored sufficiently widely, it is known to control mussel scale very effectively when applied at the correct time for the pest at 90% crawler emergence.
- Thiacloprid (Calypso) is active against a wide range of other important apple pests including apple grass aphid, sawfly, capsids, mussel scale and leaf hoppers. However, it has little activity against woolly aphid and is considered to have some adverse effects on earwigs in orchards if it is used later in the season after blossom when earwigs have populated the tree canopy. Earwigs are important natural enemies.
- Thiamethoxam (Centric) is the most broad spectrum neonicotinoid and is also very harmful to bees so can't be used in blossom or if bees are foraging. It is probably very effective against all the above pests as well as woolly aphid.

Note that these materials are largely ineffective against winter and tortrix moth caterpillars.

- Chlorpyrifos (various products.) is also moderately effective against woolly aphid though it is not systemic and will not give good control of aphids that are inaccessible to sprays. It will control other pests including caterpillars, capsids, sawfly (the latter species is controlled when chlorpyrifos is applied at petal fall) and woolly aphid.
- Several synthetic pyrethroid insecticides are also approved for control of aphids on apple but their use should be avoided as they are harmful to predatory mites and other insects.
- The use of nicotine should be avoided because of its toxicity to humans. Approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.

It is important to apply the above insecticides in warm weather conditions at the full recommended dose and in a sufficient spray volume to give adequate cover.

It is also important to apply the insecticide **early**, before large colonies form which are difficult to control once surrounded by distorted mature leaves.

Rosy apple aphid has developed strains resistant to aphicides in central and southern European countries but resistance has not been demonstrated in the UK.

- The risks of the development of resistance to insecticides should be reduced by only treating when necessary and varying the insecticides used for control.

Insecticides approved for control of aphids on apple

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of -	Safety to *Typhs*
acetamiprid	Gazelle	neonicotinoid	broad-spectrum, systemic	Aphids and Whitefly	safe
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars, sawfly,	safe

				capsids etc.	
cypermethrin	various	pyrethroid	broad spectrum	Aphids, capsids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
fatty acids	Savona	soap	broad spectrum	Aphids, scale insects	harmful
flonicamid	Teppeki, Mainman	neonicotinoid	selective	Aphids and woolly aphid	safe
nicotine*	various	alkaloid	broad spectrum	Aphids including woolly aphid, caterpillars, sawflies	harmful
pirimicarb	Aphox etc.	carbamate	selective aphicide, trans-laminar	Aphids	safe
thiacloprid	Calypso†	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids and sawfly, though not caterpillars or woolly aphid)	safe
thiamethoxam	Centric	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe

Choice of insecticides - Safety factors

	Hazards				**Harvest interval (days)**	**Max. no. sprays**	**Buffer zone Width (m)**
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
acetamiprid	no	u	h	u	14	2	20
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18

deltamethrin	no	h, i	ed	d	0	u	18
fatty acids	no	u	h	u	0	u	sm
flonicamid	no	u	h	u	21	3	sm
nicotine*	no	t, h	d	h	2	u	sm
pirimicarb	yes	t, c	h	-	3	u	sm
thiacloprid†	no	h, i	h	h	14	2	30
thiamethoxam	no	h	h	d	14	2	sm

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, t=toxic, c=closed cab required for air assisted sprayers, sm=statutory minimum of 5 m for broadcast airassisted sprayers u=uncategorised/unclassified/unspecified

† not approved for use on pear

*approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Control in organic orchards

Cultural controls such as encouraging natural enemies are useful but, in addition, early season sprays of fatty acids (Savona) is the preferred spray treatment of organic apple growers in the UK for aphids including rosy apple aphid.

- The sprays have to be applied early at the green cluster growth stage (after the overwintered eggs have hatched in spring but before reproduction occurs is best) and in high volumes so that the aphids are thoroughly wetted by the spray.
- Application is sometimes made during gentle rain.
- Control is especially important on young trees which can be very severely damaged in the years of establishment.
- Derris is also permitted for aphid control in organic apple production.
- In other European countries, an oil extracted from the neem tree is used for control of rosy apple aphid in organic orchards but it is not registered for use in the UK. It is fairly effective but precise timing of application shortly after hatching of eggs in spring is critical.

Further reading

Life cycle

- Eggs, laid in bark crevices on smaller branches and spurs and at the bases of buds, hatch in early spring before bloom.
- The aphids feed on buds and outer rosette leaves.
- They increase asexually, giving birth to live young. Numbers increase rapidly in May and June and large colonies may form.
- Winged forms are produced and these disperse to the aphid's summer host plant, plantains.
- Breeding continues on apple into August, even after winged forms have developed if new growth is available on the trees.
- In the early autumn, winged forms develop on plantains and disperse back to apple.
- The individuals that return first deposit nymphs on apple that develop into females.
- Males then disperse back from plantain to apple and mate with the females which lay eggs on the bark that overwinter.

Pest status

- An important key pest of apple which can be difficult to control with insecticides.
- The severity of attack varies considerably from year to year.
- A similar species, the pear bedstraw aphid (*Dysaphis pyri*), is an important pest of pear.

Other hosts

- Apple and related *Malus* sp. are the only winter host.
- Plantains, *Plantago* sp., are the summer host.

Varietal susceptibility

There are considerable differences in the susceptibility of different apple varieties to rosy apple aphid, but the relative susceptibility has not been adequately characterised.

- Highly susceptible varieties include Bramley, Discovery, Egremont Russet, Golden Delicious and Jonagold.
- Most other commercially grown varieties are moderately susceptible.
- Some new varieties with the Vf scab gene are reputed to be partially resistant.

Distribution

Widespread and common throughout Europe.

Damage

- First signs of damage are in early spring when outer rosette leaves of infested trusses show a slight yellowish discoloration before curling.
- As larger colonies develop, infested leaves are severely curled downward and distorted.
- They sometimes turn yellowish brown, but never red (red distorted leaves are caused by the rosy leaf curling aphid).
- Damaged fruits are often small, malformed with uneven, wrinkled and sometimes waxy skin and often develop a rosy colour.
- Sometimes, larger damaged fruits have sunken darker areas.

Recognition

Eggs
Shiny black, and found on the bark of apple trees, mainly on older wood.

Visual distinction between the eggs of different aphid species is impossible.

Adults
Pink to dark bluish grey, with a mealy powdering of white wax.

Other pests with which the rosy apple aphid may be confused

Rosy leaf curling aphid
Very similar in appearance to the rosy apple aphid, but damaged shoots turn a distinct bright red colour.

Pear bedstraw aphid
Only occurs on pear and not on apple. Rosy apple aphid does not occur on pear.

Monitoring

Visual inspection

- Orchards should be inspected regularly, preferably fortnightly, from the green cluster growth stage (April) through to mid-summer (end of June) for signs of infestation and or damage.
- Critical growth stages are late green cluster (so that a pre-blossom aphicide may be applied) and during blossom when populations are often increasing rapidly.
- On Bramley, where flowering is often very protracted when frosts occur, pre-blossom treatment is especially important as it can be several weeks before another opportunity to spray while the crop is not in flower.
- Examine at least 25 trees per orchard for signs of damage.
- The threshold for treatment increases as the season progresses but presence of the aphid at the green cluster stage, even on only one of the 25 trees inspected, is enough to warrant treatment.
- Rosy apple aphid populations are particularly damaging between bloom and early fruitlet development when fruit cell division is occurring.
- Infestations that occur after this time (more than a month after full bloom) are less damaging.

Forecasting

Work in Switzerland showed that winter eggs of rosy apple aphid hatch between 100 and 180 degree days, 50% emergence being reached at 130 degree-days above a thermal threshold of 4.5 °C.

- Temperature sums are started from 1 January. Rosy apple aphid eggs hatch a week or so after those of apple grass aphid.
- Rosy apple aphid begins to reproduce approximately 230 degree-days after emergence.
- This suggests that the optimum period for pre-bloom population monitoring for control measures extends from 180 (end of hatching) to 230 (beginning of reproduction) degree-days.
- These developments can be used for forecasting, but predictions have not been validated in the UK.

Chemical control

Spring sprays
Rosy apple aphid populations should be carefully monitored in spring at the green cluster to pink-bud growth stage and again during and after blossom.

The rosy apple aphid is easier to control shortly after eggs have hatched and before colonies develop at the green cluster growth stage. It is very difficult to control later when colonies have developed which are protected in curled, mature leaves.

- A spray of an approved aphicide should be applied **as soon as infestation is detected**.
- If only rosy apple aphid is to be controlled, then pirimicarb (Aphox etc) or flonicamid (Mainman, Teppeki) are likely to be a good choice as they are selective aphicides. Pirimicarb (Aphox etc) in particular has to be applied in warm conditions to get good results and preferably at higher spray volumes.
- The neonicotinoids acetamiprid (Gazelle), thiacloprid (Calypso) and thiamethoxam (Centric) are also effective against rosy apple aphid and will control a range of other pests depending on the material chosen.
- Acetamiprid (Gazelle) is the most selective of these materials though its activity against other apple pests has not been explored sufficiently widely. It is known to control mussel scale very effectively when applied at the correct time for the pest, at 90% crawler emergence.
- Thiacloprid (Calypso) is active against a wide range of other important apple pests including apple grass aphid, sawfly, capsids, mussel scale and leaf hoppers. However, it has little activity against woolly aphid and is considered to have some adverse effects on earwigs in orchards if it is used later in the season after blossom when earwigs have populated the tree canopy.
- Earwigs are important natural enemies.
- Thiamethoxam (Centric) is the most broad spectrum neonicotinoid and is also very harmful to bees so can't be used in blossom or if bees are foraging. It is probably very effective against all the above pests as well as woolly aphid.

Note that these materials are largely ineffective against winter and tortrix moth caterpillars.

- Chlorpyrifos (various products) is also moderately effective against woolly aphid though it is not systemic and will not give good control of aphids that are inaccessible to sprays. It will control other pests including caterpillars, capsids, sawfly (the latter species is controlled when chlorpyrifos is applied at petal fall) and woolly aphid.
- Several synthetic pyrethroid insecticides are also approved for control of aphids on apple but their use should be avoided as they are harmful to predatory mites and other insects.
- The use of nicotine should be avoided because of its toxicity to humans. Approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.

It is important to apply the above insecticides in warm weather conditions at the full recommended dose and in a sufficient spray volume to give adequate cover.

It is also important to apply the insecticide **early**, before large colonies form which are difficult to control once surrounded by distorted mature leaves.

Autumn sprays
Rosy apple aphid can readily be controlled in the autumn by one or two sprays of an aphicide in October to control males and the females (oviparae) before egg laying commences.

The advantages or spraying at this time are that the aphids, which are present on the undersides of the leaves, do not cause leaf curling at this time and are more readily directly intercepted by sprays. Another advantage is that if insecticides are used at this time, they are unlikely to result in residues on fruits.

The main disadvantage with this approach is that it is difficult to determine whether or not sprays are necessary. This decision would require careful inspection of the trees in early October to quantify the numbers of oviparae on the undersides of leaves.

- Rosy apple aphid oviparae are generally green in colour and are difficult to distinguish from oviparae of the apple grass aphid, *Rhopalosiphum insertum*, which can be very numerous. Distinguishing the species requires expert entomological examination.
- Thresholds have not been determined though it has been observed that very heavy infestations of rosy apple aphid can result the following spring if 10% of shoot leaves are infested in the autumn.
- The outcome is, in effect, that autumn treatment has to be applied as a routine.
- If only one autumn spray is applied, it may not completely preclude the need for treatment the following spring.
- However, when autumn sprays are not used, the need for almost routine treatments for rosy apple aphid in spring, often with more than one spray, is an important consideration.

Insecticide resistance

Resistance of rosy apple aphid to conventional insecticides, including OPs and pirimicarb (Aphox etc.), has been shown to occur and is a significant problem in Italy and Switzerland and is probably widespread in all apple producing regions of southern/central Europe.

- Resistance has not been shown to occur in the UK but no testing has been done. It is possible that the increased problems of control that growers have faced in the UK in recent years are due to resistance or a loss in sensitivity.
- However, an equally likely alternative explanation is that poorer control can be attributed to the loss of all systemic OP insecticides (e.g. demeton-S-methyl) for use in orchards.
- The chance of resistance developing should be reduced by avoiding repeated use of the same insecticides and by treatment only when necessary.

Cultural control

Physical methods
Organic growers are sometimes forced to physically destroy colonies to prevent them spreading.

- This is sometimes done when hand-thinning fruitlets.
- This is very labour intensive and small colonies are often missed which flare up subsequently.

Fostering natural enemies
The main cultural control approach is to foster populations of natural enemies, especially predators (see below). This can be done in several ways.

- Tolerating less harmful aphid species such as the apple grass aphid attracts predators in early spring.
- Flowering plants (e.g. corn marigold, corn camomile and mayweed) can be established in or around the orchard to provide alternative food sources, mainly nectar and pollen, for adult hover flies.
- These may then lay their eggs in aphid colonies.
- Ground herbage under the tree may also become infested with other aphid species (e.g. grasses can become infested with bird-cherry oat aphid) which can provide an alternate food source for aphid predators (e.g. ladybird adults and larvae) and parasites.
- Artificial refuges should be used to foster earwigs and other natural enemies such as lacewings.
- Ideally, a refuge should be provided in each tree. This may simply be some extra lengths of hollow tree tie round the stake.
- In orchards with high tree densities, it is likely to be impractical to provide more elaborate refuges such as half of a plastic drinks bottle containing a roll of corrugated cardboard.

Natural enemies

A wide range of predators and parasites are natural enemies of rosy apple aphid. However, when weather and tree growth conditions are favourable in spring, population increase by the aphid is too rapid for natural enemies to prevent population increase and damage. Natural enemies have a greater effect when plant growth slows or ceases in summer.

Predation of aphids and their eggs in the autumn may be more significant as the number of overwintering eggs may be substantially reduced resulting in a smaller number of colonies developing in spring. This may be the reason why more colonies often develop in spring in insecticide treated than untreated orchards.

Predatory insects and spiders

- A wide range of predatory insects prey on rosy apple aphid including earwigs, predatory anthocorid and mirid bugs, lacewing and hoverfly larvae, predatory midge larvae, ladybird adults and larvae and spiders.

Parasitic wasps

- *Ephedus persicae* is the most important species in spring but contributes little to natural control of the aphid. Ant attendance and hyperparasitism decrease the impact of parasitic wasps.

Entomopathogens

- Outbreaks of fungal pathogens (*Entomophthora* sp) have been reported from rosy apple aphid colonies occasionally causing population crashes but their importance has not been investigated adequately.

Biological control

Effective biological control approaches for this pest have not been developed.

- Artificial introduction of predatory insects is uneconomic.
- Biopesticides based on the use of entomopathogens need to be developed.

Further reading

Barbagallo, S., Cravedi, P, Passqualini, E, Patti, I, & Stroyan, H. L. G. 1997. Aphids on the principal fruit bearing crops. Bayer, Milan.123pp

Blommers, L. H. M. 1999. Probing the natural control of rosy apple aphid *Dysaphis plantaginea* (Pass.) (Homoptera: Aphididae). *IOBC/WPRS Bulletin* 22(7), 53-56.

Bonnemaison, L. 1959. Le puceron cendre du pommier (*Dysaphis plantaginea* Pass.) – Morphologie et biologie – Methods de lutte. *Annales Epiphyties* 10, 257-329.

Graf, B, Hohn, H & Hopli, H. U. 1999. Optimising the control of rosy apple aphid *Dysaphis plantaginea* (Pass.)(Homoptera: Aphididae). *IOBC/WPRS Bulletin* 22(7), 71-76.

Minks, A. K. & Harrewijn, P. 1987. Aphids, their biology, natural enemies and control. World Crop Pests, Volumes 2A, 2B and 2C. Elsevier, Amsterdam.

Rosy leaf curling aphid (Dysaphis devecta (Walker))

Rosy leaf curling aphid is a widely distributed but localised minor pest of apple.

Rosy leaf curling aphid damage

Infestations occur on the same trees (often older trees with rough bark) year after year and spread from tree to tree is slow. The life cycle involves overwintering on the tree as eggs.

Some apple varieties, including Cox, Ashmead's Kernal, Fiesta, Fortune, Gala, James Grieve, Kidd's Orange Red, Lord Lambourne, Merton Worcester, Sunset, Suntan and Winston are resistant to rosy leaf curling aphid. Others, notably Elstar, Falstaff, Idared, Golden Delicious and Worcester Pearmain, are highly susceptible. Bramley is moderately susceptible.

The aphid hatches in April at early green cluster from overwintered eggs on the bark and infests the rosette leaves which then curl and develop the characteristic red colour.

The severity of infestation by rosy leaf curling aphid should be determined in each orchard when pre-blossom pest assessments are done at green cluster. At least 25 trees should be inspected for presence/absence of the pest, concentrating on localities where the pest was seen the previous year.

It is hard to distinguish between the rosy leaf curling aphid and the rosy apple aphid but the latter does not cause the characteristic bright red coloration of leaves caused by the rosy leaf curling aphid.

Control

A localised application of an approved insecticide to control the pest should be considered where the pest is detected.

- If only rosy leaf curling, rosy apple or apple grass aphid are to be controlled, then pirimicarb (Aphox etc) or flonicamid (Mainman, Teppeki) are likely to be a good choice as they are selective aphicides.
- Pirimicarb (Aphox etc) in particular has to be applied in warm conditions to get good results and preferably at higher spray volumes.
- The neonicotinoids acetamiprid (Gazelle), thiacloprid (Calypso) and thiamethoxam (Centric) are also likely to be effective against rosy leaf curling aphid and will control a range of other pests depending on the material chosen.
- Acetamiprid (Gazelle) is the most selective of these materials though its activity against other apple pests has not been explored sufficiently widely. It is known to control mussel scale very effectively when applied at the correct time for the pest i.e. at 90% crawler emergence.
- Thiacloprid (Calypso) is active against a wide range of other important apple pests including rosy apple aphid, apple grass aphid, sawfly, capsids, mussel scale and leaf hoppers. However, it has little activity against woolly aphid and is considered to have some adverse effects on earwigs in orchards if it is used later in the season after blossom when earwigs have populated the tree canopy.
- Earwigs are important natural enemies.
- Thiamethoxam (Centric) is the most broad spectrum neonicotinoid and is also very harmful to bees so can't be used in blossom or if bees are foraging. It is probably very effective against all the above pests as well as woolly aphid.

Note that these materials are largely ineffective against winter and tortrix moth caterpillars.

- Chlorpyrifos (various products.) is also moderately effective against woolly aphid though it is not systemic and will not give good control of aphids that are inaccessible to sprays. It will control other pests including caterpillars, capsids, sawfly (the latter species is controlled when chlorpyrifos is applied at petal fall) and woolly aphid.
- Several synthetic pyrethroid insecticides are also approved for control of aphids on apple but their use should be avoided as they are harmful to predatory mites and other insects.
- The use of nicotine should be avoided because of its toxicity to humans. Approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.

It is important to apply the above insecticides in warm weather conditions at the full recommended dose and in a sufficient spray volume to give adequate cover.

It is also important to apply the insecticide early, before large colonies form which are difficult to control once surrounded by distorted mature leaves.

Insecticides approved for control of aphids on apple

Choice of insecticides - efficacy factors					
Active ingredient	**Trade name (examples)**	**Class**	**Selectivity**	**Approved for control of -**	**Safety to *Typhs***

acetamiprid	Gazelle	neonicotinoid	broad-spectrum, systemic	Aphids and Whitefly	safe
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars, sawfly, capsids etc.	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids, capsids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
fatty acids	Savona	soap	broad spectrum	Aphids, scale insects	harmful
flonicamid	Teppeki, Mainman	neonicotinoid	selective	Aphids and woolly aphid	safe
nicotine*	various	alkaloid	broad spectrum	Aphids including woolly aphid, caterpillars, sawflies	harmful
pirimicarb	Aphox etc.	carbamate	selective aphicide, trans-laminar	Aphids	safe
thiacloprid	Calypso†	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid. (Also likely to control capsids and sawfly, though not caterpillars or woolly aphid)	safe
Thiamethoxam	Centric	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe

Choice of insecticides - Safety factors

	Hazards				**Harvest interval (days)**	**Max. no. sprays**	**Buffer zone Width (m)**

	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
acetamiprid	no	u	h	u	14	2	20
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
fatty acids	no	u	h	u	0	u	sm
flonicamid	no	u	h	u	21	3	sm
nicotine*	no	t, h	d	h	2	u	sm
pirimicarb	yes	t, c	h	-	3	u	sm
thiacloprid†	no	h, i	h	h	14	2	30
thiamethoxam	no	h	h	d	14	2	sm

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, t=toxic, c=closed cab required for air assisted sprayers, sm=statutory minimum of 5 m for broadcast airassisted sprayers u=uncategorised/unclassified/unspecified

† not approved for use on pear

*approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Control in organic orchards

In organic orchards the pest should be tolerated except where significant damage is being caused especially to young trees. Thus rosy leaf curling aphid is often ignored or tolerated in organic orchards because of the localised nature of the damage it causes. However, it can become important on some varieties in certain years.

- Cultural methods of control mainly rely on natural enemies, which should be encouraged by providing artificial refuges and flowering plants in and around the orchard.
- Early season sprays of fatty acids (Savona) is the preferred treatment of organic apple growers in the UK for aphids including rosy leaf curling aphid.
- The sprays have to be applied early at the green cluster growth stage (after the overwintered eggs have hatched in spring but before reproduction occurs is best) and in high volumes so that the aphids are thoroughly wetted by the spray.
- Application is sometimes made during gentle rain.

Further reading

Life cycle

- Overwintered eggs are laid under loose bark or in deep crevices in the bark of the main trunk and branches of the tree.
- The eggs hatch in spring at early green cluster and colonies develop on the undersides of the rosette leaves.
- Later, infestations develop in the young shoots.
- In the third generation, winged and wingless females are produced and in the fourth generation, winged males but wingless females.
- These sexual forms mate and eggs are laid from mid-June to mid-July.
- Colonies die out in mid-summer, most live aphids disappearing by the end of July.

- There is no evidence of infestations spreading from tree to tree by winged migrants.
- Spread from tree to tree is slow and may be caused by walking aphids.

Pest status

A minor pest of apple.

Other hosts

Only breeds on apple and some *Malus* sp.

Varietal susceptibility

- Some apple varieties are resistant to rosy leaf curling aphid, notably Cox.
- Others, such as Bramley, are susceptible and some, notably Golden Delicious and Worcester Pearmain are highly susceptible.
- The single gene responsible for resistance has been identified and is now used in apple breeding programmes.
- At East Malling Research, where the resistance gene was first identified, all recently released new varieties have included the resistance gene.

Distribution

Widely distributed but local, often occurring on the same few trees in an orchard in successive years.

Recognition

Egg
Shiny black and found on the bark of apple trees.

Adult
Grey to dark bluish grey, dusted with a white waxy powder and with short, black, tapering honey tubes which are flanged at the tip.

Other pests with which rosy leaf curling aphid may be confused

Rosy apple aphid

- The adult aphid and nymphs of rosy apple aphid and rosy leaf curling aphid are very similar in appearance.
- Both pests cause leaf curling but the rosy apple aphid does not cause the bright red coloration of leaves which is only caused by the rosy leaf curling aphid.

Apple leaf curling midge

- Curling of leaves in the shoot tips is often caused by larvae of the apple leaf midge and the leaf curls often develop a reddish colour.
- However, leaves damaged by this pest are tightly curled, often upwards, and contain small, white or pinkish maggot like larvae of the apple leaf midge.

Monitoring

The severity of infestation by rosy leaf curling aphid should be determined in each orchard when pest assessments are done before blossom at the green cluster to pink bud growth stage.

- Attention should be focussed on highly susceptible varieties (e.g. Golden Delicious) and in places where the pest occurred the previous year.
- Examine the rosette leaves over the whole tree on at least 25 trees per orchard.
- Localised application of an insecticide to control green apple aphid should be considered where infestation is detected.

Forecasting

Forecasting models for rosy leaf curling aphid have not been developed.

Control methods

Chemical control

A localised application of an approved insecticide should be considered where the pest is detected.

- If only rosy leaf curling, rosy apple or apple grass aphid are to be controlled, then pirimicarb (Aphox etc) or flonicamid (Mainman, Teppeki) are likely to be a good choice as they are selective aphicides.
- Pirimicarb (Aphox etc) in particular has to be applied in warm conditions to get good results and preferably at higher spray volumes.
- The neonicotinoids acetamiprid (Gazelle), thiacloprid (Calypso) and thiamethoxam (Centric) are also likely to be effective against rosy leaf curling aphid and will control a range of other pests depending on the material chosen.
- Acetamiprid (Gazelle) is the most selective of these materials though its activity against other apple pests has not been explored sufficiently widely. It is known to control mussel scale very effectively when applied at the correct time for the pest at 90% crawler emergence.
- Thiacloprid (Calypso) is active against a wide range of other important apple pests including rosy apple aphid, apple grass aphid, sawfly, capsids, mussel scale and leaf hoppers. However, it has little activity against woolly aphid and is considered to have some adverse effects on earwigs in orchards if it is used later in the season after blossom when earwigs have populated the tree canopy.
- Earwigs are important natural enemies.
- Thiamethoxam (Centric) is the most broad spectrum neonicotinoid and is also very harmful to bees so can't be used in blossom or if bees are foraging. It is probably very effective against all the above pests as well as woolly aphid.

Note that these materials are largely ineffective against winter and tortrix moth caterpillars.

- Chlorpyrifos (various products.) is also moderately effective against woolly aphid though it is not systemic and will not give good control of aphids that are inaccessible to sprays. It will control other pests including caterpillars, capsids, sawfly (the latter species is controlled when chlorpyrifos is applied at petal fall) and woolly aphid.
- Several synthetic pyrethroid insecticides are also approved for control of aphids on apple but their use should be avoided as they are harmful to predatory mites and other insects.
- The use of nicotine should be avoided because of its toxicity to humans. Approval for the use and storage of all products containing nicotine is allowed only until 8 June 2010.

It is important to apply insecticides in warm weather conditions at the full recommended dose and in a sufficient spray volume to give adequate cover.

It is also important to apply the insecticide early, before large colonies form which are difficult to control once surrounded by distorted mature leaves.

Cultural control

Rosy leaf curling aphid is a pest that occurs on the same trees year after year and only spreads slowly to adjacent trees.

- Where infestation is on a limited scale, it may be practical to remove and destroy infested shoots.
- Natural enemies should be encouraged by avoiding the use of broad-spectrum insecticides and by providing flowering plants in and around the orchard.
- Artificial refuges should be used to foster earwigs and other natural enemies such as lacewings.
- Ideally, a refuge should be provided in each tree. This may simply be some extra lengths of hollow tree tie round the stake.
- In orchards with high tree densities, it is likely to be impractical to provide more elaborate refuges such as half of a plastic drinks bottle containing a roll of corrugated cardboard.

Natural enemies

Predatory insects and spiders

- A wide range of predatory insects, including anthocorid, mirid and nabid bugs, ladybird adults and larvae, hoverfly, predatory midge and lacewing larvae and spiders feed on rosy leaf curling aphid.

Parasitic wasps

- The parasitic wasps *Ephedrus persice, Ephedrus platigator* and *Trioxys angelicae* are known to parasitise rosy leaf curling aphid.
- The parasites lay their eggs (usually singly) in the body of the aphid which continues to feed during the early stages of development of the parasite.
- The parasite eventually pupates within or beneath the skeleton of the aphid, forming a so-called 'aphid mummy'.
- Although parasitic wasps are common natural enemies of rosy leaf curling aphid, they are not usually abundant enough to greatly reduce aphid populations.

Fungal parasites

- Outbreaks of fungal diseases (*Entomophthora* sp.) probably occur in rosy leaf curling aphid colonies. Outbreaks occur in warm, humid or wet conditions.

Biological control

Biological control approaches have not been developed for rosy leaf curling aphid.

Further reading

Barbagallo, S., Cravedi, P, Passqualini, E, Patti, I, & Stroyan, H. L. G. 1997. Aphids on the principal fruit bearing crops. Bayer, Milan.123pp

Minks, A. K. & Harrewijn, P. 1987. Aphids, their biology, natural enemies and control. World Crop Pests, Volumes 2A, 2B and 2C. Elsevier, Amsterdam.

Life cycle

- There are two generations per annum in the UK.
- Larval development has five instar stages.
- The pest overwinters as a second or third instar larva in a silken hibernaculum in crevices in the bark etc.
- There is often considerable winter mortality which is sometimes an important limiting factor in population development.
- After emergence in spring shortly after bud-burst, individual larvae feed amongst the buds, characteristically tying them and the rosette leaves together with webbing.
- On early apple varieties and on pears, larval feeding produces cavities in the receptacle, which later heal to form corky scars characteristic of early caterpillar feeding.
- Larvae pupate when fully fed, normally around blossom time of Cox.
- First generation adult moths emerge in June.
- Eggs are laid in batches on the foliage. These hatch in 7-10 days depending on temperature (see 'Forecasting'.
- Cool and wet weather conditions at the time of moth flight and/or during egg-hatch limit population increase.
- Many larvae migrate to the growing points in shoots where they form leaf rolls.
- In July and August more mature larvae feed on fruits before pupation in August.
- A second generation of adults occurs in August and September, depositing eggs on leaves and also directly onto fruits.
- These hatch and the young larvae feed beneath silken webs spun on the under-surfaces of leaves, often at a junction between the main and a side vein.
- In late September and October, larvae have reached the second or third instar stage and migrate to crevices in the bark to overwinter.

Pest status

- The summer fruit tortrix moth is an important secondary pest of apple and pear. It attacks foliage and fruit.
- Natural enemies reduce populations in the unsprayed situation.

Other hosts

- Recorded from over 70 species of plant, mainly from the family Rosaceae, including many hedgerow and woodland trees and shrubs.

Varietal susceptibility

- Apple varieties with fruits that are short stalked and/or which hang in clusters, tend to be most susceptible.
- Bramley and Discovery are highly susceptible.

Distribution

Not a native of Britain. First recorded at Teynham in Kent in 1950, for many years it was confined to the South East, especially Kent and Essex.

- More recently it has spread across much of southern and central England where it is now widespread and common.
- It is reputed to be absent from the West Midlands.

Damage

Damage to foliage is unimportant. Damage to fruits occurs at three different times during fruit development:

Overwintered larvae

- Feeding cavities in the receptacle of flowers and young fruitlets later heal to form corky scars characteristic of early caterpillar feeding on mature fruits.

First generation larvae

- Young caterpillars make small, shallow holes in the skin of fruits in July and early August.
- Larger caterpillars graze shallow irregular patches in the skin, especially at the point where fruits are in contact.

Second generation larvae

- Damage is similar to that caused by first generation larvae but occurs in late August and September and appears more freshly formed and may be in progress at harvest.

Recognition

Adult (resting)
Length 8-11 mm, light brown with darker brown markings.

Egg
Flat, oval, light green. Black centre when mature. Laid in scale-like batches on leaves and, for the second generation, sometimes on fruits.

Larvae
Up to 18-20 mm long. Yellow-green, olive green or dark green, usually with a brown head, though head colour is not diagnostic. Spins fine webbing and often occurs in leaf rolls or beneath a leaf tied to fruit.

Other pests with which summer fruit tortrix moth may be confused

Larvae of several leaf-rolling tortrix moths are very similar and are difficult to distinguish from each other.

- Larvae of the fruit tree tortrix moth, *Archips podana*, occur commonly in orchards in the UK and are particularly difficult to distinguish from those of the summer fruit tortrix moth.

Monitoring

Pheromone traps
The flight activity of male moths should be monitored using sex pheromone traps. The delta design is used widely.

- Traps should be set out in orchards shortly after blossom.
- Each orchard should be individually monitored with a trap.
- The traps should be hung from the branch of a tree at mid canopy height in the centre of the orchard and oriented to allow flow through of the prevailing wind.
- The number of moths should be recorded weekly, and captured moths removed.
- Lures should be changed every 4-6 weeks as recommended by the manufacturer.
- It is important to change them before the second generation.
- Sticky bases should be changed if their effectiveness declines.
- The threshold for determining whether the pest is a problem in an orchard is 30 moths per trap per week.
- However, temperature sums to predict egg hatch to determine correct timing of egg hatch sprays should be started from the date when the catch exceeds 5 moths per trap (see 'Forecasting').

Shoot damage

- During the first half of July, leaves tied by spinning larvae are easily recognisable on the top of the shoots.
- If shoot damage exceeds 5-8%, a curative treatment should be applied immediately or postponed to the beginning of egg-hatch of the second generation.

Fruit damage

- Inspecting fruits for damage, either whilst developing on the tree, at harvest or during grading (remembering that badly damaged fruit may have been discarded at harvest), indicates if populations have been high and whether treatment is likely to be required for the next generation or the next season.

Trunk banding

- Trunk bands can be set on a sample number of trees in early September and the number of overwintering larvae counted during the dormant period.

Chemical control

Various insecticides that are approved for control of colding moth, totrix moths or for general caterpillar control are likely to control summer fruit tortrix moth, but diflubenzuron (Dimilin) notably has poor efficacy against summer fruit tortrix moth and should not be used.

- Summer fruit tortrix moth may be controlled with chlorpyrifos (various products), indoxacarb (Steward), methoxyfenozide (Runner) or spinosad (Tracer), or with the biocontrol agent *Bacillus thuringiensis*, applied to coincide with egg hatch, usually in June.
- *Bacillus thuringiensis* is considered to be of only moderate efficacy.
- The first spray should be applied at the onset of egg hatch of the first generation. Further sprays should be applied at 7-10 day intervals until the egg hatch period has ended.
- (Chlorpyrifos should not be used on pear at this time as it is harmful to the anthocorid predators of pear sucker.)
- Synthetic pyrethroids are highly effective but their use should be avoided as they are harmful to predatory mites and other beneficial insects
- A pre-blossom spray of chlorpyrifos, indoxacarb (Steward) or methoxyfenozide (Runner), often applied to control early season caterpillars and aphids, will reduce populations of overwintered summer fruit tortrix moth caterpillars, but is unlikely to be sufficiently effective to prevent damaging first and second generations developing subsequently.
- The onset of egg laying is taken as the date when the pheromone trap catch exceeds 5 moths/trap/week.
- If traps are only examined weekly, the date when this occurred can often be pin-pointed more accurately by examination of daily temperature records.
- The moths fly when dusk temperatures exceed 15 °C.

- The onset of the egg hatching period occurs 7-21 days later, depending on temperature. It can be calculated accurately from daily maximum and minimum air temperatures using the look-up table (see 'Forecasting').
- The daily percentage egg development amounts are summed from the date of the onset of egg laying. When the sum reaches 90%, egg hatch is imminent and the first spray should be applied.
- A second generation occurs in August and September which can be damaging on later harvested varieties. The second generation may be controlled in the same way.
- However, the 14 day harvest interval of chlorpyrifos may preclude use of this product at this time. Detectable residues of chlorpyrifos may occur on the fruit at harvest if chlorpyrifos is used in August or September. This is undesirable, even if Maximum Residue Levels are not exceeded. *Bacillus thuringiensis* should be used.

Control with the Juvenile Hormone Analogue insecticide fenoxycarb (Insegar):

- Juvenile hormone is an insect hormone that controls metamorphosis from larva to pupa in some insects. The concentration of the hormone falls to very low levels when caterpillars are mature, signalling metamorphosis to the pupal state.
- Fenoxycarb (Insegar) is a juvenile hormone analogue which acts on mature caterpillars that are about to pupate. Juvenile hormone also plays a role in egg formation in the adult insect and in egg development after oviposition.
- However, these modes of action of fenoxycarb (Insegar) are of lesser importance in the summer fruit tortrix moth (though the effects on eggs are important for codling moth against which the chemical is ovicidal).
- Fenoxycarb (Insegar) is applied against mature (last instar) overwintered summer fruit tortrix moth caterpillars in spring whilst they are feeding on the blossom trusses and before pupation.
- The aim is to virtually eradicate the pest so that subsequently first and second generation numbers are so low that control is unnecessary.
- The timing of spray application is critical. If application is too early, most of the caterpillars will be in the fourth instar stage of development, which is less susceptible to the insecticide.
- If the application is too late, a significant proportion of the caterpillars will have pupated and these will not be affected. The critical last instar development stage often coincides with the blossom time of Cox apples.
- Fenoxycarb (Insegar) has a high risk to bees and must not be applied during bloom. The insecticide does not appear to affect adults directly but affects the brood.
- On apple, a spray of fenoxycarb (Insegar) should be applied just before bloom at the 'pink balloon' growth stage.
- If high populations of the pest are present (as indicated by pheromone trap catches or damage the previous year or by the presence of significant numbers of summer fruit tortrix moth caterpillars at the green cluster growth stage), a second application should be made at 80% petal fall or later.
- This second application will also give 2-3 weeks ovicidal protection against codling moth. It is important to check bees are not foraging.
- The success of the treatment should be evaluated by monitoring populations of the pest subsequently with pheromone traps.
- Regular use of fenoxycarb will suppress populations to very low levels.
- A moderate pheromone trap does not indicate that treatment has been unsuccessful.
- Female moths that develop from caterpillars that have fed on low doses of fenoxycarb are often sterile.

Insecticide resistance

Strains of summer fruit tortrix moth, that are less susceptible to conventional insecticides (such as chlorpyrifos) than strains that occur in unsprayed orchards, have been shown to occur in the UK. However, the reduction in susceptibility is small.

Forecasting

The rate of development of each of the developmental stages of summer fruit tortrix moth is only completed when a specific heat sum has accumulated. The specific heat sums are known and can be calculated each day from the daily maximum and minimum air temperature. The forecasting model PESTMAN can be used to give approximate predictions of the timing of occurrence of each of the life stages of the pest.

Forecasting the time that overwintered caterpillars reach the last instar stage (for timing Insegar sprays)

- Overwintered larvae reach the last instar development stage approximately 75‖100 day-degrees C above a threshold temperature of 8°C starting from 1 January.

Forecasting the start and peak of first generation adults

- The start and peak of the flight of first generation adult moths occurs approximately 170 and 210 day-degrees C above a threshold temperature of 10°C after 1 January.

Forecasting the start and peak of second generation adults

- The start and peak of the flight of second generation adult moths occurs approximately 616 and 693 day-degrees C above a threshold temperature of 10°C after 1 January.

Forecasting the timing of egg hatch

- Egg development takes approximately 103 day-degrees C above a threshold temperature of 8.6°C.
- The percentage egg development that accrues at various daily maximum and minimum air temperatures is given in the look-up table.
- Sum the daily percentage egg development amounts starting from the day the first pheromone trap catch of 5 or more moths occurred.
- Apply the first egg hatch spray when the temperature sum reaches 90-100%.
- If above threshold catches continue for more than one further week, a second spray may be necessary 7-10 days later.

Cultural control

Trees which have a dense canopy and vigorous shoot growth tend to support greater populations of caterpillars. If shoot growth then ceases when caterpillars are young, due to water stress and/or a heavy fruit load, the caterpillars tend to move to feed on fruits, especially those in clusters, and damage intensifies.

- Avoiding this situation by tree management reduces losses.
- The cultural control approaches recommended for codling moth are likely also to be effective in controlling summer fruit tortrix moth, though hygiene measures need to be modified to suit this particular species.
- Furnishing the trees with artificial refuges for earwigs and other insect predators is likely to help reduce young caterpillar populations.
- Ideally, a refuge should be provided in each tree. This may simply be some extra lengths of hollow tree tie round the stake.
- In orchards with high tree densities, it is likely to be impractical to provide more elaborate refuges such as half of a plastic drinks bottle containing a roll of corrugated cardboard.

Natural enemies

Insectivorous birds

- Tits especially pick overwintering larvae from bark crevices, but do not forage specifically for the pest unless population densities are very high and for this reason are of limited value only.

Egg parasites

- The egg parasitic wasp *Trichogramma* can be introduced (4 releases of 2.5 m per ha have been shown to reduce damage by 40-85%) but such introductions are not cost effective.

Larval parasites

- The parasitic wasp *Colpoclypeus florus* is an external parasite of third to fifth instar summer fruit tortrix moth larvae.
- The parasite can be seen attached behind the head of its host.

Predatory insects

- Earwigs and predatory mirid and anthocorid bugs feed of eggs and young larvae.

Virus diseases

- A nucleopolyhedrovirus (AoNPV) and two strains of a granulovirus (AoGV) of summer fruit tortrix moth are known (see 'Biological control' below).
- These are normally found in association with commercial applications of biocontrol agents, though natural infections of AoGV were found in two orchards near Faversham in Kent in 1993.

Biological control

Bacillis thurigiensis

- A programme of weekly sprays of *Bacillus thuringiensis* (Bt) throughout the egg hatch period gives fairly good control, though control may not be as good as that achieved with conventional or Insect Growth Regulator insecticides (see below).
- Bt has to be ingested to act and is most effective in warm weather when caterpillars are feeding actively.
- The bacterium produces a crystalline toxin. The insect dies from the effects of this toxin rather than from pathogenesis due to the bacterium.
- Bt is of short persistence as it is degraded by heat and UV light.
- It is most effective against newly hatched larvae before they form leaf rolls in which they feed internally and are inaccessible to sprays.
- The first spray should be applied at the onset of egg hatch which should be determined from pheromone trap catches and egg development sums calculated from the daily maximum and minimum air temperature (see 'Forecasting').
- Bt is not detected by conventional pesticide residue analysis.

Viruses

- Three baculoviruses of summer fruit tortrix moth have been tested for use in the field in Europe including a nucleopolyhedrovirus (AoNPV) and a granulovirus (AoGV).
- AoNPV can control summer fruit tortrix very effectively and is highly host-specific but the virus is uneconomic to produce and is not available commercially.
- AoGV has a very slow pathogenesis. Newly hatched larvae become infected in the first instar development stage and only die when they reach the final development stage.
- They can live longer than uninfected larvae and larval damage to fruit may not decrease in the short term.
- In the longer term, a high degree of control can be obtained. The virus may persist for several generations.
- A commercial formulation is produced in Switzerland but is not registered for use in the UK.

Biotechnological control

Pheromone mating disruption

- Pheromone mating disruption systems have been developed for summer fruit tortrix moth in continental Europe.
- One system uses red spaghetti double tube plastic dispensers, one tube containing the pheromone, the other a metal wire to give rigidity.
- The dispensers are wrapped round the branch of a tree.
- A typical application rate is 1000 dispensers per ha, one application being required per season.
- The system was developed to control summer fruit tortrix moth and other tortrix moths, such as *Pandemis heparana* and *Archips rosana,* and uses a common pheromone component (Z11-14:Ac).
- Pheromone mating disruption systems have a number of important limitations.
- They are only effective if populations of the target pest are low initially; they have to be applied over a large area; they are generally costly in comparison with insecticides and they have a high labour requirement for application.
- There are no pheromone mating disruption systems approved for use in the UK.

Further reading

Charmillot, P.–J. & Brunner, J. F. 1989. Summerfruit Tortrix, *Adoxophyes orana*: Life cycle, warning system and control. Entomologia Hellenica 7, 17-26.

Cross, J. V. 1997. The susceptibility of summer fruit tortrix moth, *Adoxophyes orana* (Lepidoptera: Tortricidae), to chlorpyrifos and strategies for insecticidal control in orchards. *Annals of Applied Biology* 131, 197-212.

Van der Geest, L. P. S. & Evenhuis, H. H. (Eds). 1991. *Tortricid Pests, Their Biology, Natural Enemies and Control* . World Crop Pests, Vol. 5. Elsevier, Amsterdam.

Summer fruit tortrix moth (Adoxophyes orana Fischer von Röslerstamm)

The summer fruit tortrix moth is an important secondary pest of apples and pears, especially in eastern and south-

The summer fruit tortrix moth is an important secondary pest of apples and pears, especially in eastern and south eastern England. The life cycle involves two generations a year in the UK.

Short stalked varieties such as Bramley and Discovery are most susceptible, but all varieties of apple and pear may be attacked.

Damage to foliage is unimportant but damage to fruits occurs at three different times during fruit development.

Larvae of several leaf-rolling tortrix moths are very similar and are difficult to distinguish from each other. The pest should be monitored with pheromone traps weekly from petal fall of apple to the end of August.

The need to treat for the pest should be determined by high trap catches (>30 moths per trap per week) or damage the previous season, or by the presence of high populations of caterpillars in blossom trusses in spring before bloom.

Control

Various insecticides that are approved for control of colding moth, totrix moths or for general caterpillar control are likely to control summer fruit tortrix moth but diflubenzuron (Dimilin) notably has poor efficacy against summer fruit tortrix moth and should not be used.

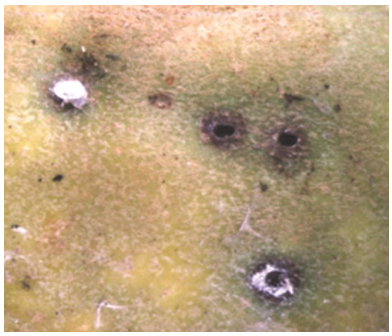
- The pest may be controlled by one or two sprays of fenoxycarb (Insegar) timed to coincide with the critical fifth instar development stage of overwintered caterpillars in spring.
- The aim is to eradicate overwintered caterpillars so that sprays against first and second generation caterpillars in summer are not necessary.
- On apple, the first spray should be applied shortly before bloom of Cox at the pink balloon growth stage.
- Where populations are high, a second spray should be applied at petal fall, as soon as bee activity has ceased.
- Fenoxycarb (Insegar) has a high risk to bees and must not be applied during flowering. The pre-blossom spray must be applied before early pollinators come into bloom.
- The grass should be cut before application to remove flowering plants. Avoid using fenoxycarb (Insegar) if neighbouring crops are flowering (e.g. oilseed rape).
- Alternatively, the pest may be controlled with chlorpyrifos (various products), indoxacarb (Steward), methoxyfenozide (Runner) or spinosad (Tracer), or with *Bacillus thuringiensis*, applied to coincide with egg hatch usually in June.
- *Bacillus thuringiensis* is considered to be of only moderate efficacy. The first spray should be applied at the onset of egg hatch of the first generation. Further sprays should be applied at 7-10 day intervals until the egg hatch period has ended.
- Synthetic pyrethroids are highly effective but their use should be avoided as they are harmful to predatory mites and other beneficial insects.
- The onset of egg laying is taken as the date when the pheromone trap catch exceeds 5 moths/trap/week. If traps are only examined weekly, the date when this occurred can often be pin-pointed more accurately by examination of daily temperature records.
- The moths fly when dusk temperatures exceed 15 °C. The onset of the egg hatching period occurs 7-21 days later, depending on temperature. It can be accurately forecast from daily maximum and minimum air temperatures using the look-up table provided.
- The daily percentage egg development amounts are summed from the date of the onset of egg laying. When the sum reaches 90%, egg hatch is imminent and the first spray should be applied.
- A second generation occurs in August and September which can be damaging on later harvested varieties. The second generation may be controlled in the same way.
- However, the 14 day harvest interval of chlorpyrifos may preclude use of this product at this time. Detectable residues of chlorpyrifos may occur on the fruit at harvest if chlorpyrifos is used in August or September. This is undesirable, even if Maximum Residue Levels are not exceeded. *Bacillus thuringiensis* should be used.

Insecticides approved for control of codling, tortrix moths or caterpillars on apple and pear which are likely to control summer fruit tortrix moth

Summer fruit tortrix adults Male (left) Female (right)

Summer fruit tortrix egg batch on leaf

Summer fruit tortrix larva



Small holes in fruit caused by larvae

Fruit damage

Choice of insecticides - efficacy factors

Active ingredient	Trade names	Class[1]	Selectivity	Label rec's[2]	Safety to *Typhs*	Suggested interval between sprays (days)
Bacillus thuringiensis	Dipel	bacterial insecticide	selective to caterpillars	c (SOLA)	safe	3-14
bifenthrin	Brigade	pyrethroid	broad-spectrum	Red spider mite	harmful	14-21
chlorpyrifos	Dursban, etc.	OP	broad spectrum	c, cm, t	safe	14-21
cypermethrin	various	pyrethroid	broad spectrum	c, cm, t	harmful	14-21
deltamethrin	Decis	pyrethroid	broad spectrum	cm, t	harmful	21
indoxacarb	Steward	oxadiazine	selective	c, cm, ftt, sft	u	10-14
fenoxycarb	Insegar	JHA	selective	sft	safe	21
methoxyfenozide	Runner	MAC	selective	c	safe	u
nicotine*	various	alkaloid	broad spectrum	c	harmful	7
spinosad	Tracer	neural blocker	selective	C, cm, ftt,sft	safe	10

Choice of insecticides - Safety factor

Read and and follow the label before applying any sprays

	Hazards[2]				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
Bacillus thuringiensis	no	u	u	u	0	u	u
bifenthrin	no	h,i	ed	ed	u	2	30
chlorpyrifos	yes	h, i	ed	ed	14	3	18

cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
indoxacarb	no	h	ed	u	7	3	15
fenoxycarb	no	u	d	d	42	2	18
methoxyfenozide	no	u	u	u	14	3	5
nicotine*	no	t, h	d	h	2	u	u
spinosad	no	u	ed	u	7	4	40

Keys: [1]OP=organophosphate, CSI=chitin synthesis inhibitor, JHA=juvenile hormone analogue

[2]c=caterpillars, ftt=fruit tree tortrix, sft=summer fruit tortrix, t=tortrix

[3]d=dangerous, ed=extremely dangerous, h=harmful, i=irritant, t=toxic, u=no hazard specified

* approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Control in organic orchards

Summer fruit tortrix moth should be less problematic in organic orchards because populations are regulated by natural enemies, especially parasitic wasps and probably also because tree vigour is lower in organic orchards (see 'Cultural control').

- If control measures are necessary, sprays of *Bacillus thuringiensis* or spinosad (Tracer), should be applied in the same way as in conventional orchards (see above).

Further reading

Winter moth (Operophtera brumata (L.))

Winter moth is an important pest of apple and pear. The life cycle involves wingless females crawling up the tree trunk to lay eggs in the bark.

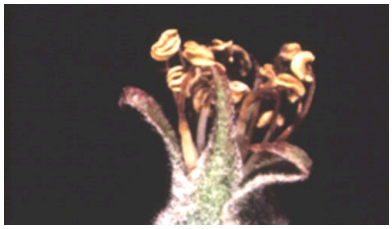
The green caterpillars feed amongst the blossom trusses from green cluster to early June. They damage developing fruitlets by feeding on them. The cavities heal to form characteristic corky scars.

The pest is usually most abundant at the edges of orchards adjacent to woodland (especially oak) and hedgerows.

Although superficially similar to some other caterpillar pests they can be distinguished by having only two pairs of prolegs.

Populations of larvae should be monitored by visually inspecting trusses at green cluster to pink bud before bloom. If more than 5% of trusses are infested, a pre-blossom insecticide application is justified.

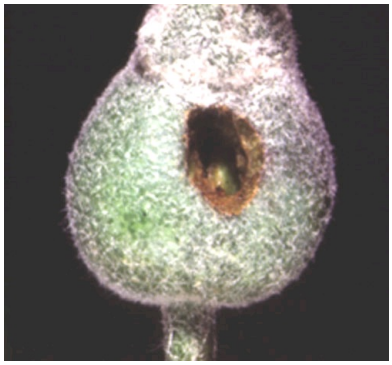
Winter moth larva



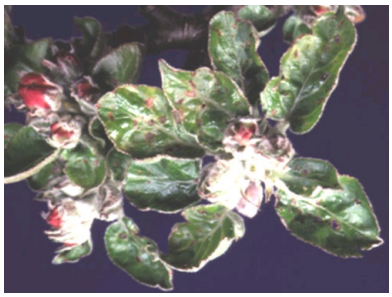
Control

A wide range of insecticides are approved for control of caterpillar pests on apple and all these are likely to control winter moth, which is sensitive to insecticides. Some growers apply a pre-blossom spray of a broad-spectrum insecticide (e.g. chlorpyrifos) to control aphids and caterpillars including those of the winter moth. But many other insecticides when applied before blossom will also control winter moth and have varying degrees of activity against different pests.

- Diflubenzuron (Dimilin), indoxacarb (Steward) and methoxyfenozide are selective materials which are likely to control caterpillars only and have little effect on aphids.
- Indoxacarb (Steward) may give some control of capsids. Spinosad (Tracer) may also be effective.
- Fenoxycarb (Insegar) is not a good choice because it only controls caterpillars in their later stages of development and will not prevent early damage to buds, blossoms and fruitlets.
- Synthetic pyrethroids are also highly effective against winter moth but their use should be avoided because they are harmful to important orchard natural enemies including the orchard predatory mite.
- Nicotine is toxic and also should be avoided. In any case, approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.



Winter moth caterpillar feeding cavities in fruitlet



Winter moth damage to truss

Corky scars on fruit at harvest

Insecticides approved for control of winter moth, codling moth, tortrix moths or caterpillars on apple and/or pear

Choice of insecticides - efficacy factors

Active ingredient	Trade names	Class[1]	Selectivity	Label rec's[2]	Safety to *Typhs*	Suggested interval between sprays (days)
Bacillus thuringiensis	Dipel	bacterial insecticide	selective to caterpillars	c (SOLA)	safe	3-14
bifenthrin	brigade	pyrethroid	broad-spectrum	Red spider mite	harmful	14-21
chlorpyrifos	Dursban, etc.	OP	broad spectrum	c, cm, t	safe	14-21
cypermethrin	various	pyrethroid	broad spectrum	c, cm, t	harmful	14-21
deltamethrin	Decis	pyrethroid	broad spectrum	cm, t	harmful	21

diflubenzuron	Dimilin	CSI	selective	c, cm, ftt	safe	28
indoxacarb	Steward	oxadiazine	selective	c, cm, ftt, sft	u	10-14
methoxyfenozide	Runner	MAC	selective	c	safe	u
nicotine*	various	alkaloid	broad spectrum	c	harmful	7
spinosad	Tracer	neural blocker	selective	C, cm, ftt,sft	safe	10

Choice of insecticides - Safety factor

Read and and follow the label before applying any sprays

	Hazards[2]				**Harvest interval**	**Max. no. sprays**	**Buffer zone Width (m)**
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees	**(days)**		
Bacillus thuringiensis	no	u	u	u	0	u	u
bifenthrin	no	h,i	ed	ed	u	2	30
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
diflubenzuron	no	u	u	u	14	3	u
indoxacarb	no	h	ed	u	7	3	15
methoxyfenozide	no	u	u	u	14	3	5
nicotine*	no	t, h	d	h	2	u	u
spinosad	no	u	ed	u	7	4	40

Keys: [1]OP=organophosphate, CSI=chitin synthesis inhibitor

[2]c=caterpillars, ftt=fruit tree tortrix, sft=summer fruit tortrix, t=tortrix

[3]d=dangerous, ed=extremely dangerous, h=harmful, i=irritant, t=toxic, u=no hazard specified

* approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Control in organic orchards

Winter moth is often one of the most damaging pests in organic orchards.

- In organic orchards it should be controlled using cultural control methods (see 'Cultural control').
- Spinosad (Tracer) and *Bacillus thuringiensis* (Dipel) are the only materials approved for organic orchards.
- *Bacillus thuringiensis* can be fairly effective providing temperatures are warm at and shortly after application so that caterpillars are feeding actively.

Further reading

Life cycle

- Adults occur from October to January but are most numerous in November and December.
- On emergence from pupation, the spider-like female crawls up the trunk of the tree and after mating, lays 100-200 eggs singly in crevices in the bark.
- Eggs hatch in spring mainly from bud-burst to green cluster, but some hatch later.
- The tiny caterpillars are often blown from tree to tree and infestations may also spread to fruit trees from adjacent woodland in this way.
- Feeding continues until late May or early June.
- When mature, the larvae drop to the ground to pupate.

Pest status

Important pest of apple and pear. Attacks fruit directly and so is damaging at low population densities, though can be controlled readily with insecticides.

Other hosts

A wide range of deciduous and coniferous trees, especially oak.

Varietal susceptibility

All varieties of apple and pear are susceptible and host plant resistance is not known to occur.

Distribution

Widespread and common, especially in wooded areas.

Damage

- Foliage and buds are devoured indiscriminately in spring by larvae, which bite holes in developing fruitlets.
- These either drop prematurely or develop into malformed fruits with corky scars.

Recognition

Adult male
Flies at night in winter. Wingspan 22-28 mm, forewings rounded, greyish brown and with darker wavy cross-lines.

Adult female
Found on tree trunks and branches in winter. Wings reduced to stubs; body 5–6 mm long, dark brown mottled with greyish yellow.

Egg
Occur singly in bark crevices; 0.5 x 0.4 mm; oval, pale yellowish-green, soon becoming orange red with pitted surface.

Larva
Looper habit, up to 25 mm long. Pale green with dark green dorsal stripe and several whitish or creamish-yellow stripes along back and sides, including a pale yellow line passing through the spiracles. Abdomen has two pairs of prolegs.

Other pests with which winter moth may be confused

Tortrix moth caterpillars

- Tortrix moth caterpillars often occur in blossom trusses in spring and, when tiny, can be confused with winter moth caterpillars.
- However, tortrix moth caterpillars have 5 pairs of abdominal prolegs.

Clouded drab moth caterpillars

- Clouded drab moth caterpillars occur commonly in the shoots of apple post blossom and have a similar green colour appearance to winter moth but are quite different if examined closely.
- They gave 5 pairs of abdominal prolegs.

Monitoring

Pre-blossom visual assessment

- Inspect at least 100 trusses (e.g. 4 on each of 25 trees) per orchard for signs of damage or infestation by winter moth larvae at the green cluster to pink bud growth stage of apple.
- Inspect trees at the edge of the orchard adjacent to woodland or hedgerows where the risk of infestation is high, as well as those in the centre and other parts of the orchard where the risk of infestation is lower.
- If damage is seen, open up truss to see if a winter moth larva is present.
- A hand lens should be used to distinguish small caterpillars of the winter moth (2 pairs of prolegs) from those of tortrix or noctuid (e.g. clouded drab) moths (5

pairs of prolegs).

- Treatment with an insecticide is justified if 5% or more of trusses are infested.

Late blossom visual assessment

- The same methods are used as for the pre-blossom visual assessment.
- However, the treatment threshold is 3% of trusses infested, lower than the pre-blossom threshold.

Late blossom assessment using the beating method

- Beat at least 20 branches per orchard over a beating tray.
- The treatment threshold is 1 caterpillar or more per 20 beats.

Damage at harvest

- The percentage of fruits with corky scars, characteristic of early caterpillar feeding, should be monitored at harvest and during grading.
- If the percentage exceeds 0.1%, this is an indication that control methods that season were not optimal and more effective measures are likely to be needed the following year.

Pheromone traps for adults

- The female-produced sex pheromone of winter moth has been identified and lures containing synthetic pheromone can be acquired from specialist manufacturers and suppliers.
- Pheromone traps placed in orchards from October to January often catch large numbers of males but these may be attracted over considerable distances from woodland and hedgerows and may have little significance in terms of populations in the orchard. For this reason they are not used commercially.

Grease banding of trunks

- A band of a recommended grease may be pasted round the lower trunk of a sample of trees in September to October to monitor the number of ascending females in winter.
- Note that grease bands may be phytotoxic to young trees.

Forecasting

Useful forecasting models for winter moth have not been developed.

Chemical control

Chemical control is the principal means of control in UK orchards. A wide range of insecticides are approved for control of caterpillar pests on apple. The pest is sensitive to insecticides and can be controlled cheaply and effectively.

- It is common practice for growers to apply a pre-blossom spray of a broad-spectrum insecticide, usually chlorpyrifos, to control early season caterpillars and aphids.
- A spray of an approved insecticide should be applied at the green cluster to pink bud growth stage.
- Later spraying is preferable because late hatching larvae are more likely to be killed.
- Broad-spectrum chemicals are harmful or dangerous to bees and should not be applied during blossom.
- Many other insecticides when applied before blossom will also control winter moth and have varying degrees of activity against different pests.
- Diflubenzuron (Dimilin), indoxacarb (Steward) and methoxyfenozide are selective materials which are likely to control caterpillars only, and have little effect on aphids.
- Indoxacarb (Steward) may give some control of capsids. Spinosad (Tracer) may also be effective.
- Fenoxycarb (Insegar) is not a good choice because it only controls caterpillars in their latter stages of development and will not prevent early damage to buds, blossoms and fruitlets.
- Synthetic pyrethroids (bifenthrin (Brigade), cypermethrin (various products) and deltamethrin (Decis etc)) are also highly effective against winter moth but their use should be avoided because they are harmful to important orchard natural enemies including the orchard predatory mite.
- Nicotine is toxic and also should be avoided. Approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.
- *Bacillus thuringiensis* is the only material approved for organic orchards. It can be fairly effective, providing that temperatures are warm at and shortly after application so that caterpillars are feeding actively.

Insecticide resistance

- As winter moth is abundant in woodland and wild places that are not treated with insecticides and which provide the source of infestation for the pest and because the pest has only one generation per annum, the probability of insecticide resistance developing is very low.

Cultural control

Spatial isolation

- Winter moth is a denizen of woodland trees, especially oak.
- The pest is much less of a problem in orchards which are isolated from such woodland and larger hedgerows.

Grease banding of trunks

- A band of a recommended grease may be pasted round the lower trunk of each tree in September to October to prevent females ascending the tree in winter.
- This method is effective, but labour intensive, and is not usually done in large-scale commercial orchards.
- The band has to be renewed annually so that a sticky surface to the band is maintained.
- To reduce labour costs, it might be appropriate to treat the trees round the periphery of the orchard only, or areas close to woodland where the risk of infestation is high.
- Grease banding is harmful to some predatory insects, such as earwigs, which climb the tree from the soil in spring.
- Also, it can be phytotoxic to young trees.

Natural enemies

Predators

- Insectivorous birds and many species of polyphagous predatory insects feed occasionally on winter moth larvae.
- However, their impact on populations of winter moth larvae in orchards is limited.

Parasitoids

Many species of parasitoid attack the larvae or cocoons of the winter moth and these are its most important natural enemies.

- The tachinid fly *Cyzenis albicans* is one of the most common.
- It lays up to 1000 eggs which are attached singly to leaves that already have some feeding damage by winter moth larvae.
- The eggs are ingested with the food and the parasite larva soon begins to consume the host tissue.
- Parasitism rates can be high (30-60%) when the density of winter moth larvae is high, but are much lower (<5%) in commercial orchards.
- The ichneumonid parasitic wasp *Agrypon flaveolatum*, which attacks winter moth larvae, is another common species which may play a role in reducing populations.
- Parasitic wasps are sensitive to broad-spectrum insecticides, which are especially harmful to adults.

Bacteria

- *Bacillus thuriengiensis* is a pathogen of winter moth larvae but infections are normally associated with applications of the bacterium as a biological control agent.

Viruses

- Nucleopolyhedroviruses and cypoviruses have been recorded from winter moth.

Biological control

One or more sprays of *Bacillus thuringiensis* (Bt) before blossom will control winter moth larvae, providing temperatures are high enough for the caterpillars to be feeding actively.

- The bacteria and the crystal toxin which it produces, have to be ingested in order to act.
- The main problem is that caterpillars are often feeding in or amongst the buds or in furled rosette leaves where they are inaccessible to sprays.
- The bacterium is degraded by heat and UV light so is of short persistence.
- For these reasons, it is probable that more than one spray will be required for a high standard of control.
- *Bacillus thuringiensis* is harmless to bees and may be applied during blossom if necessary.

Further reading

Briggs, J. B. 1955. Notes on the biology and identification of some allies of the winter moth (*Operophtera brumata* (L.). *Report of East Malling Research Station 1955* , 141-146.

Briggs, J. B. 1957. Some features of the biology of the winter moth (*Operophtera brumata* (L.)) on top fruits. *Journal of Horticultural Science* 32(2) 108-125.

Hand, S. C., Ellis, N. W. & Stoakley, J. T. 1987 Development of a pheromone monitoring system for the winter moth, *Operophtera brumata* (L.), in apples and in Sitka spruce. *Crop Protection*. 6: 3, 191-196

Hardman, J. M;. & Gaul, S. O. 1990. Mixtures of *Bacillus thuringiensis* and pyrethroids control winter moth (Lepidoptera: Geometridae) in orchards without causing outbreaks of mites. *Journal of Economic Entomology*. 83: 3, 920-936

Holliday, N. J. 1977. Population ecology of winter moth (*Operophtera brumata*) on apple in relation to larval dispersal and time of bud burst. *Journal of Applied Ecology* 14: 3, 803‖813.

Woolly aphid (Eriosoma lanigerum (Hausmann))

Woolly aphid is a sporadic pest of apple, which is sometimes present at low levels in orchards but only increases to cause problems in some years. Damage is expected to occur in years after warm winters when aphid colonies increase in early summer and spread onto extension growth. The entire life cycle is passed on the host tree.

Woolly aphid

Earwigs, ladybirds and the parasitic wasp *Aphelinus mali* are important natural enemies of woolly aphid and usually regulate populations to below damaging levels.

Artificial refuges should be provided for earwigs in orchards where woolly aphid is a problem and the use of pesticides harmful to earwigs and other natural enemies should be avoided.

The aphid itself is brown to greyish purple but is easily recognised as it produces conspicuous secretions of white woolly wax.

Orchards should be inspected for the pest (i.e. for the colonies that produce conspicuous masses of white woolly wax) at the end of blossom, in June and again in mid-summer.

The June assessment is critical. At least 25 trees per orchard should be inspected. If one or more trees in the sample has woolly aphid, in the extension growth, treatment with an insecticide is justified.

Woolly aphid colony with wax blown away

Control

- Chlorpyrifos (various products.), flonicamid (Mainman, Teppeki), nicotine (various products) and thiamethoxam (Centric) are specifically recommended for control of woolly aphid on apple.
- Pirimicarb (Aphox etc.) can also give good control if applied in higher spray volumes in warmer weather conditions.
- Flonicamid (Mainman, Teppeki) or pirimicarb (Aphox etc) are good choices because they are selective, have low toxicity to natural enemies and are partially systemic.
- Chlorpyrifos (Dursban etc.) is also effective. Sprays of chlorpyrifos (various products), often applied for other pests, have an important benefit of suppressing woolly aphid in conventional orchards.
- Thiamethoxam (Centric) is highly effective against woolly aphid but is a broad spectrum insecticide that is likely to have harmful effects on some important orchard natural enemies. It is dangerous to bees and care must be taken to avoid spraying when bees are foraging. Application is restricted to post-blossom.
- Use of synthetic pyrethroids, which are harmful to natural enemies, or nicotine, which is toxic, should be avoided.
- Note also that approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.

- Thiacloprid (Calypso) has little or no effect on woolly aphid. Calypso may possibly be harmful to earwigs, the most important natural enemy of woolly aphid. If this is the case, sprays of thiacloprid (Calypso) in mid- and late summer when earwigs are present in the tree, could cause later outbreaks of woolly aphid.
- Higher volume sprays are likely to give best results.

Insecticides approved for control of aphids on apple that are recommended or likely to control woolly aphid.

Thiacloprid (Calypso) is not listed here because although it is effective against other aphid species on apple and many other pests, it is ineffective against woolly aphid

Choice of insecticides - efficacy factors

Active ingredient	Trade name (examples)	Class	Selectivity	Approved for control of -	Safety to *Typhs*
acetamiprid	Gazelle	neonicotinoid	broad-spectrum, systemic	Aphids and Whitefly	safe
chlorpyrifos	Dursban etc.	organo-phosphate	broad spectrum	Aphids including woolly aphid, caterpillars, sawfly, capsids etc.	safe
cypermethrin	various	pyrethroid	broad spectrum	Aphids, capsids, caterpillars, codling & tortrix moths, sawflies, apple sucker	harmful
deltamethrin	Decis etc.	pyrethroid	broad spectrum	Aphids, codling & tortrix moths	harmful
fatty acids	Savona	soap	broad spectrum	Aphids, scale insects	harmful
flonicamid	Teppeki, Mainman	neonicotinoid	selective	Aphids and woolly aphid	safe
nicotine*	various	alkaloid	broad spectrum	Aphids including woolly aphid, caterpillars, sawflies	harmful
pirimicarb	Aphox etc.	carbamate	selective aphicide, trans-laminar	Aphids	safe
thiamethoxam	Centric	neonicotinoid	broad-spectrum, systemic	Rosy apple aphid, green apple aphid, woolly aphid and pear sucker	safe

Choice of insecticides - Safety factors

	Hazards				Harvest interval (days)	Max. no. sprays	Buffer zone Width (m)
	Anticholin-Esterase?	Humans	Fish & aquatic life	Bees			
acetamiprid	no	u	h	u	14	2	20
chlorpyrifos	yes	h, i	ed	ed	14	3	18
cypermethrin	no	h, i	ed	d	0	5	18
deltamethrin	no	h, i	ed	d	0	u	18
fatty acids	no	u	h	u	0	u	sm
flonicamid	no	u	h	u	21	3	sm
nicotine*	no	t, h	d	h	2	u	sm
pirimicarb	yes	t, c	h	-	3	u	sm
thiamethoxam	no	h	h	d	14	2	sm

h=harmful, i=irritant, d=dangerous, ed=extremely dangerous, t=toxic, c=closed cab required for air assisted sprayers, sm=statutory minimum of 5 m for broadcast airassisted sprayers u=uncategorised/unclassified/unspecified

* approval for use and storage of all products containing nicotine is allowed only until 08 June 2010

Control in organic orchards

In organic orchards where the pest is often troublesome, emphasis should be placed on cultural control measures such as the provision of artificial refuges for earwigs and, if practicable, physical destruction of colonies in spring.

- High volume sprays of fatty acids (potassium soap) (Savona) should be applied when damaging infestations develop.

Further reading

Life history

- The entire life cycle is passed on the host tree. Young aphids overwinter in sheltered positions such as in cracks or under loose bark. They are not covered with wool so are inconspicuous at this time.
- In March or April they become active and start to secrete wool from their wax glands.
- Breeding colonies are present by the end of May. In spring and early summer, colonies are found mainly on spurs and branches, especially round pruning wounds.
- Later, the infestations may spread to the young growth, particularly water shoots. They are found on the axils of leaves at first then spread out along the whole length of the shoot.
- A few winged aphids are produced in July and may fly off to infest other trees. Other winged aphids occur in September and produce egg-laying females.
- Although a single egg is produced by each female, there is no further development which can only occur on American Elm (*Ulmus amiricana*). Thus the life cycle consists essentially of wingless female aphids producing living young.
- Breeding slows down in the autumn and adult aphids die during winter.
- Depending on yearly temperatures, there are approximately 8-12 generations per year.

Pest status

An important pest of apple which periodically increases and in some seasons in some orchards.

Other hosts

Also attacks Japanese quince (*Chaenomales* sp.), *Cotoneaster* sp., Hawthorn, *Malus* sp. and *Pyracantha* sp.

Varietal susceptibility

Apple varieties vary somewhat in their susceptibility to woolly aphid (e.g. Bramley is more susceptible than Cox) but commercially-grown apple varieties are not resistant. The relative susceptibility of varieties has not been characterised adequately.

- Resistant rootstocks have been bred by crosses between Northern Spy, which is highly resistant, and various Malling rootstocks which resulted in the Malling-Merton (MM) series of apple rootstocks which are highly resistant to woolly aphid. However, the rootstock does not confer resistance to the scion.
- The Malling-Merton rootstock MM106 is a semi-dwarfing woolly aphid resistant rootstock which is widely grown in the UK.
- The MM rootstocks have been very valuable in countries where root infestation occurs (Australia, South Africa and North America) but the resistance of rootstocks is of limited benefit in the UK where root infestation does not occur.
- In other countries, isolated cases of infestation by local races of woolly aphid occur on resistant rootstocks.

Distribution

- Common and widespread in the UK.
- Woolly aphid originated in the eastern part of North America and was first noticed in Britain in 1787.
- It now occurs in all countries where apples are grown having been distributed on nursery material.

Damage

- The colonies occur on bark and aphids do not infest the foliage or fruits directly.
- Galls often form on the branches at the point where aphids have fed.
- The galls often split open allowing entry for diseases such as canker or *Gloeosporium* sp.
- The main damage is caused by contamination of fruits and foliage with honeydew, wax, dead aphids etc..
- Although woolly aphid colonies are conspicuous, the amount of injury to the established tree is probably less than the appearance suggests.
- At harvest, infestations can be a severe nuisance to pickers.

Other pests with which woolly aphid may be confused

Woolly aphid infestations and the damage they cause are unique on apple and are unlikely to be confused with other pests.

Monitoring

Woolly aphid colonies are readily visible and visual inspection of the orchard is the main monitoring method.

- The aphid is collected by beating and this can indicate when low populations are present which have otherwise been missed.
- A sample of at least 25, preferably 50, trees should be inspected for the pest in early June.
- A specific inspection for this pest should be made.
- It is too easy to miss the obvious.
- The presence of colonies on the current year's extension growth is the critical factor and the economic threshold is normally considered to be 2 trees in a sample of 50 with aphids on the current year's growth.

Forecasting

Useful forecasting models for woolly aphid have not been developed.

Chemical control

Attacks of woolly aphid tend to be sporadic and it is important to watch for sign of infestation moving onto young shoots in June (see 'Monitoring') and treat only when necessary.

- A high volume spray of an approved insecticide should be applied in spring or early summer as soon as potentially damaging infestations are detected.
- Successful control depends on efficient wetting and good distribution of spray.
- High volume spraying is likely to be more effective as the spray has to penetrate the protective woolly covering of the aphid and reach colonies living in cracks and on the undersides of branches.
- Chlorpyrifos (various products.), flonicamid (Mainman, Teppeki), nicotine (various products) and thiamethoxam (Centric) are specifically recommended for control of woolly aphid on apple.
- Pirimicarb (Aphox etc.) can also give good control if applied in higher spray volumes in warmer weather conditions.
- Flonicamid (Mainman, Teppeki) or pirimicarb (Aphox etc) are good choices because they are selective, have low toxicity to natural enemies and are partially systemic.
- Chlorpyrifos (Dursban etc.) is also effective. Sprays of chlorpyrifos (various products), often applied for other pests, have an important benefit of suppressing woolly aphid in conventional orchards.
- Thiamethoxam (Centric) is highly effective against woolly aphid but is a broad spectrum insecticide that is likely to have harmful effects on some important orchard natural enemies. It is dangerous to bees and care must be taken to avoid spraying when bees are foraging. Application is restricted to post-blossom.
- Use of synthetic pyrethroids, which are harmful to natural enemies, or nicotine, which is toxic should be avoided.
- Note that approval for use and storage of all products containing nicotine is allowed only until 08 June 2010.
- Thiacloprid (Calypso) has little or no effect on woolly aphid. Calypso may possibly be harmful to earwigs, the most important natural enemy of woolly aphid. If this is the case, sprays of thiacloprid (Calypso) in mid- and late summer, when earwigs are present in the tree, could cause later outbreaks of woolly aphid.

Natural enemies, cultural and biological control

Cultural control

Physical destruction

- It is possible to destroy colonies physically e.g. with a scrubbing brush in May and early June while they are localised on the trunk and before spread to young shoots may occur. This approach is only likely to be practical on a limited scale or where tree density is low.

Cultural practices to foster natural enemies

- The main cultural control approach is to foster populations of natural enemies, especially predators. This can be done in several ways.
- Artificial refuges should be used to foster earwigs, which are important natural enemies of woolly aphid, as well as other natural enemies such as lacewings.
- Ideally, a refuge should be provided in each tree. This may simply be some extra lengths of hollow tree tie round the stake. In orchards with high tree densities, it is likely to be impractical to provide more elaborate refuges such as half of a plastic drinks bottle containing a roll of corrugated cardboard.
- Flowering plants (e.g. corn marigold, corn camomile and mayweed) can be established in or around the orchard to provide alternative food sources, mainly nectar and pollen, for adult hover flies. These may then lay their eggs in aphid colonies.
- Ground herbage under the tree may also become infested with other aphid species (e.g. grasses can become infested with bird-cherry oat aphid) which can provide an alternate food source for aphid predators (e.g. ladybird adults and larvae) and parasites.

Natural enemies

Natural enemies play an important part in naturally regulating woolly aphid populations. If natural enemies are encouraged and not harmed by broad-spectrum pesticides, woolly aphid is seldom a serious pest of apple.

Insect predators

- Many insect predators prey on woolly aphid.
- The common European earwig, *Forficula auricularia*, is an important predator of aphids and often prevents damaging infestations developing. S
- prays of diflubenzuron (Dimilin) in summer, especially applied at night, reduce earwig populations and have been shown to cause outbreaks of woolly aphid.
- Adult ladybirds like *Exochomus quadripustulatus* are important predators early in the season.

Parasitic wasps

- The parasitic wasp *Aphelinus mali* is an important natural enemy of woolly aphid.
- It was deliberately introduced into Europe during the 1920s and 1930s (see Biological control below).
- The adult wasp is 0.7-1.0 mm long and mainly black, with the antennae, each hind femora and the base of the abdomen yellow.
- First adults emerge during bloom, about 120 day-degrees above a threshold of 9.4ºC from 1 January.
- They are active and may be seen running about in the close vicinity of the host colonies.
- Females lay a single egg in each host with a preference for third instar nymphs. An average of 85 eggs is laid by each female.
- The parasite develops within the host aphid. Attacked aphids cease to produce wax so that blackish, naked parasitised individuals soon become obvious and may be exposed by blowing away the wax from the colony with a sharp puff of breath.
- Rates of parasitism vary with environmental conditions. The parasite is not favoured by humid conditions.
- There are 4 to 5 parasite generations each year. The parasite overwinters as larvae or pupae in dead host mummies.
- In general, the parasitoid is rarely able to control the aphid alone in the field (see biocontrol below) but does contribute to natural regulation of the pest as part of a natural enemy complex.
- The adult parasite is sensitive to broad-spectrum insecticides (e.g. chlorpyrifos (Dursban etc.) or synthetic pyrethroids). It is probable that residues of such insecticides on bark are harmful to the adult parasite for a considerable period after spraying.

Biological control

Natural populations of the important predators and parasites of woolly aphid should be fostered (see 'natural enemies' and 'cultural control' above).

- Artificial introductions of predators or parasites from biological control suppliers are unlikely to be economic.
- The parasitic wasp, *Aphelinus mali,* could be introduced from other orchards if it is absent.
- This is done by collecting branches bearing parasitised aphids and placing them near woolly aphid colonies in the orchard where they are to be introduced.
- This is best done in good weather in early summer.

Further reading

Barbagallo, S., Cravedi, P, Passqualini, E, Patti, I, & Stroyan, H. L. G. 1997. Aphids on the principal fruit bearing crops. Bayer, Milan.123pp

Minks, A. K. & Harrewijn, P. 1987. Aphids, their biology, natural enemies and control. World Crop Pests, Volumes 2A, 2B and 2C. Elsevier, Amsterdam.