Vine weevil control in soft fruit crops

Figure 1. Adult vine weevil and characteristic notching on strawberry leaf

Vine weevil (Figure 1) remains a major pest of soft fruit crops. This factsheet gives practical information on the biology and control of vine weevil in soft fruit crops, drawing on results from research funded by AHDB Horticulture and others.

Action points

- **Check for adult activity and characteristic leaf notching from April onwards.**
- **Check around the roots and crowns for larvae, by lifting some plants or knocking them out of their containers from March to November.**
- **Before planting plants provided in pots or trays, check a sample of plants for vine weevil larvae around the roots.**
- **Practice annual cropping of strawberry crops if possible, as keeping crops for more than one year increases the risk of vine weevil damage as populations have more time to build up.**
- **Avoid planting strawberry plants into used bags or substrate in troughs as this will increase the risk of vine weevil infestation.**
- **In top-table strawberries, consider using barrier glue on support legs to reduce the risk of adult vine weevils climbing up to strawberry plants.**
- **Plan a biological control strategy for vine weevil within an Integrated Pest Management (IPM) programme.**
- **Apply entomopathogenic nematodes in April/early May if live overwintered larvae are found. Repeat in late August and early September, making two applications 2-4 weeks apart.**
- **If considering using the entomopathogenic fungus Met52 Granular Bioinsecticide, use before planting in spring as an incorporation treatment or as a post-planting mulch if practical. Do not rely on Met52 alone for vine weevil control, but use as part of an IPM programme.**

Introduction

The vine weevil *(Otiorhynchus sulcatus*) is native to temperate areas of Europe including the UK. In the wild, it can be found in hedges, windbreaks and woodland margins feeding on a range of host plants including trees such as yew, many herbaceous plants and certain weeds. The adult weevils feed on leaves, flowers and developing fruiting laterals and the larvae feed on the roots and can cause severe damage. Vine weevil adults can also fall or crawl into punnets if disturbed from their daytime refuges during picking and be a crop contaminant. Many soft fruit crops can be damaged by the pest including strawberry, raspberry, blackberry, currants and blueberry. With many of these crops now grown under protection for at least part of the year, and in substrate rather than field soil, growing conditions are very suitable for vine weevil egg survival and larval development. There are now very few options for effective chemical control of the pest and growers are under increasing pressure to reduce the use of conventional crop protection products. Therefore the use of biological control methods for vine weevil is now essential for effective management of the pest.

Biology and plant damage

Adults

Vine weevils are all female and so reproduce without mating (parthenogenetically). This means that only one weevil is required to start an infestation.

Adult weevils are 8.5–11.5 mm long (Figure 1 – Front cover). The adult weevils are dull black or dark grey in colour but with short tufts of orange hairs on the wing cases, giving the weevils a speckled look. The wing cases are fused together and so adult weevils are unable to fly and instead walk from one area to another.

When disturbed, adult weevils ‘play dead’ by lying still with their legs curled up. As they often hide during the day in leaf debris, under pots or beneath polythene and ground-cover matting mulch, they are easily missed.

They are usually only active at night but may occasionally be seen in the day, during unfavourable conditions such as periods of extreme heat or drought.

Adult weevils remain active within host crops for as long as temperatures remain warm enough. Recent work in AHDB Horticulture-funded project HNS 195 has shown that feeding and egg laying may continue at temperatures as low as 6°C. Some adults may overwinter in leaf litter and other sheltered areas. The number of adults successfully overwintering is determined by the severity of the winter. Overwintered adults may be seen from as early as April. These individuals may start feeding soon after they become active but do not start to lay eggs during the first five weeks of activity in spring. Most adult weevils, however, emerge from pupae in the soil or growing media after completing the final stages of development in the spring. These young adults emerge over an extended period, usually from May/June onwards. Young adult weevils feed for approximately one month before egg laying starts from June onwards. Feeding by adult weevils results in characteristic leaf notching (Figure 2). Feeding by adults may also take place on flowers and on developing fruiting laterals in cane fruit crops (especially protected crops), often severing them some 2–3 cm from the cane node. Many soft fruit crops may be attacked, including strawberry, raspberry, blackberry, currants and blueberry. In addition, weed species such as dock, fat hen, dandelion, mallow, orache and plantain are also suitable hosts.

Each adult can lay over 300 eggs outdoors. They are likely to lay more eggs when they are found in glasshouses or polytunnels. Under optimum conditions, a single weevil can lay 1,600 eggs during its lifetime. Egg laying may start as early as April (by overwintered adults) and continue for as long as conditions remain favourable, often into October and November. Eggs are laid at night, typically into cracks in the soil or growing medium, but also occasionally on the surface of the growing media or on the leaves, stems and crowns of plants.

Figure 2. Adult leaf notching to blackberry leaves

Eggs

Eggs are spherical and 0.8 mm in diameter. When first laid the eggs are white but soon they turn chestnut brown in colour (Figure 3) and are very hard to see in the growing medium. The time taken for the eggs to hatch is temperature-dependent; at around 20°C egg hatch occurs after around two weeks. This period is shortened at higher temperatures and extended at lower temperatures.

Larvae

The larvae that hatch out of the eggs from late June onwards are white (larvae may appear off-white or pale pink when they feed on some soft fruit roots such as strawberry), legless, have a chestnut brown head capsule and often hold themselves in a C-shape (Figure 4). Young larvae tend to feed on fine fibrous roots in the root ball while older larvae may burrow into roots and plant crowns. Vine weevil larvae feeding is associated with orange coloured frass (droppings) found around strawberry plant crowns (Figure 5) or on structural roots of blackcurrant bushes.

Feeding damage over the winter often results in affected plants dying. Where root feeding has been less severe, growth may be stunted in spring and yields suppressed. In strawberry, flowers that have been initiated may fail to develop. Damage associated with feeding by vine weevil larvae tends to occur in patches within the crop and can be seen as areas of dieback or plant death in strawberries. Root systems in cane fruit crops are generally more extensive than in strawberry or bush fruit crops and higher levels of root feeding are required for noticeable damage to occur. Affected canes either fail to break bud in the spring or may wilt soon after. Damage is likely to be much more pronounced in stressed crops, such as in drought conditions.

Light soils favour the survival of larvae and often allow rapid population build-up, whereas heavy clay soils are much less suitable for this pest. Larvae are typically able to move more easily through growing media than soils and can feed on a greater proportion of roots when they are contained within a relatively small volume in the pots or bags. Once larvae are inside plant roots and crowns, they are more difficult to control. The larvae moult several times over the summer and early autumn, reaching a maximum size of about 12 mm (Figure 4).

Like the adults, the larvae in the compost will remain active and continue to feed as long as conditions remain favourable. In outdoor situations larvae typically continue to feed until the end of October, but under protection this period may be extended. They stop feeding with the onset of low temperatures, but even freezing conditions are unlikely to kill them. In spring, feeding may commence again until the larvae pupate. Plant damage / water stress does not often show until spring when the remaining roots are eaten or stem bases are girdled. Severe damage can lead to plant collapse and death.

Pupae

Pupae are creamy white but unlike the larvae, the folded up legs can be seen on the underside of the body (Figure 6 - overleaf). Pupae are typically found within cells made of the soil or substrate in which the plant is grown.

Figure 3. Vine weevil eggs are white when first laid, then turn brown before hatching

Figure 4. Vine weevil larva with brown head capsule and no legs

Figure 5. Vine weevil larva in strawberry plant crown with orange frass

Figure 6. Vine weevil pupa with legs folded beneath the body

When disturbed, the pupae may move slightly but they cannot walk. New adults emerge two to three weeks after pupation begins.

The life cycle of vine weevil under UK conditions is shown in Figure 7. Outdoors this typically takes between nine and 11 months; with the greatest time being spent as a larva, feeding on roots. In heated areas, such as glasshouses, the life cycle may be compressed and take as little as four months and all life cycle stages may be present at the same time. This means that potentially up to two generations may be completed within the year.

Sources of infestation

Potential sources of infestation in soft fruit crops include:

- Resident overwintered vine weevil adults or larvae in the previous year's crop
- Adults moving into crops from neighbouring infested crops, weeds, surrounding hedges, windbreaks and trees
- Eggs or larvae in bought-in tray or potted plants
- Adults moved around on staff clothing and shoes, machinery, punnets, trays, sledges and bins used for transporting propagation material

Behaviour and monitoring

By understanding their behaviour it is possible to monitor for adult weevil infestations. Defra-funded studies using tiny electronic tags (Figure 8) have shown that most adult weevils move only short distances (around 40 cm per day) within a favourable strawberry crop. As such, weevils are likely to remain close to the area in which they emerged, unless their habitat is disturbed, or becomes unsuitable for other reasons such as drought, death of host plant or absence of suitable host plants.
Under such conditions adults are capable of moving over 50m in search of new crops.

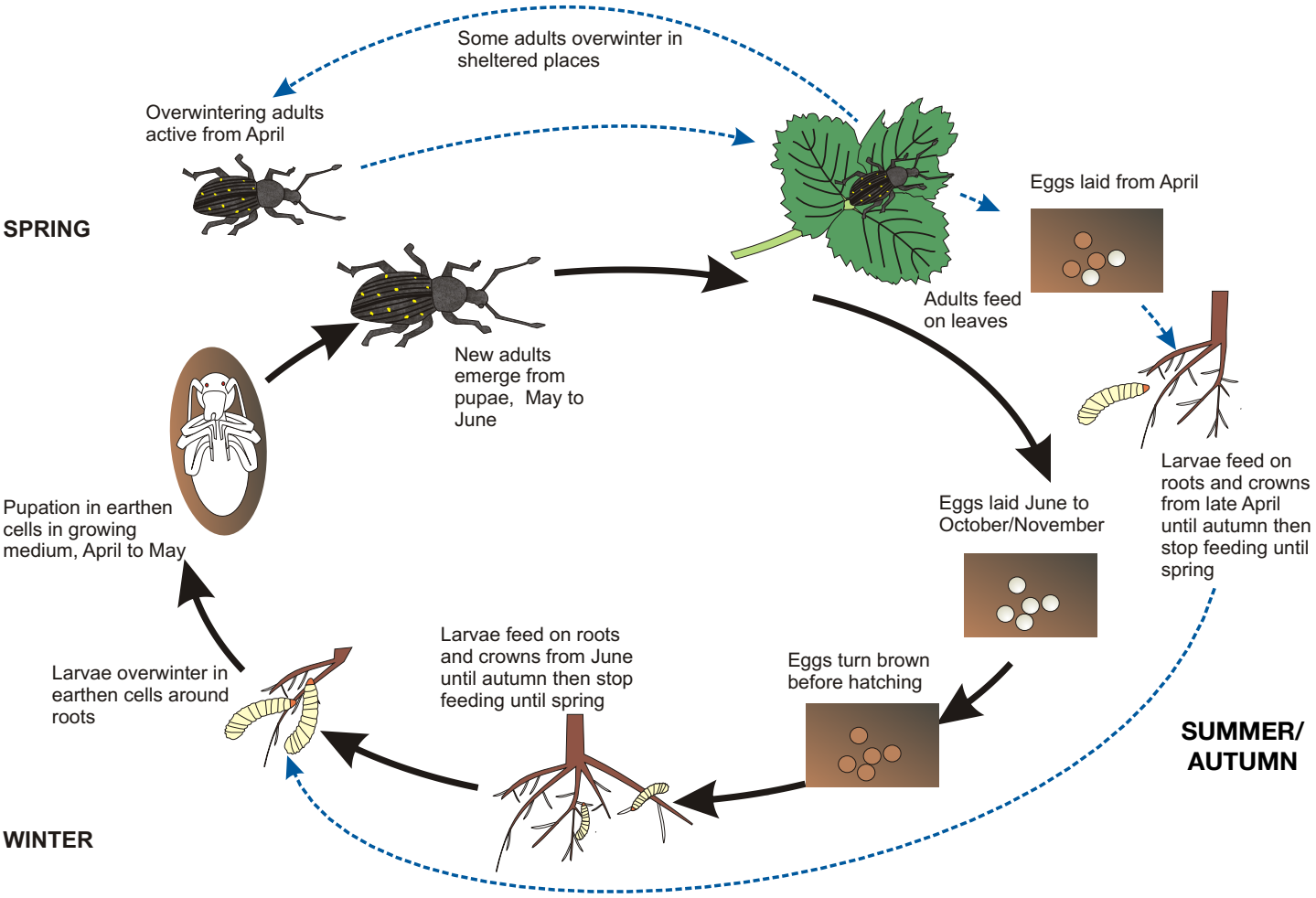

Figure 7. Life cycle of vine weevil under UK conditions

Monitoring techniques

Adult weevils tend to become active soon after dusk when they search for suitable host plants to feed on. A range of differing monitoring techniques can be employed:

- Go out at night with a powerful torch and look for them on the leaves of the crop. As vine weevil adults are very sensitive to movement, but not light, they will rapidly drop off the plant and 'play dead' if disturbed, so can be easily missed. If plants are gently shaken the adult weevils will fall and can then be easily seen on light coloured surfaces such as white material placed under the plants.
- Also look for vine weevils aggregated together under plastic mulches, ground covers and old leaves and other debris at soil or growing media level as well as in narrow gaps and ridges, such as those found beneath or around the rims of troughs and pots.
- Another useful method of monitoring is to place a length of grooved board, piece of corrugated plastic or cardboard under or near to containerised stock. The weevils may congregate under the board (Figure 9) and can be found by inspecting it regularly during the daytime.
- An alternative is to take two plant pots of the same size, fill both with straw and secure the open end of the pots together using some tape. Place the pots on their side within the crop. The weevils will enter the pots through the drainage holes in the bases of the pots and congregate together in the straw.
- Create pitfall traps placed close to a suspected infestation. However, bear in mind that such traps will also catch beneficial insects such as ground beetles. To create a pitfall trap, bury a plastic cup in the ground up to its lip and coat the upper inside edge with grease to stop the weevils crawling out. To prevent the trap from filling with irrigation water or rain, invert a 3 litre pot (with its drain holes covered with tape) over the pitfall and cut 'legs' into the pot's rim, so the weevils can crawl underneath it into the trap.
- Results in AHDB Horticulture-funded project HNS 195 have shown that a commercially made vine weevil trap is a more effective monitoring tool than grooved boards, corrugated materials or pitfall traps. This simple trap is made of black plastic and is shaped to allow weevils to enter the trap but not leave. Although the trap is commercially made overseas, it is not yet available in the UK.
- The most visible sign of infestation throughout much of the year is the feeding by adult weevils that causes notching along leaf margins (Figures 1 and 2). In cane fruit crops, grazing or severing of fruiting laterals may also be observed. It is not always easy to spot this damage however, as it may be hidden or only present on a few leaves or laterals. In strawberry crops, larvae can often be detected in the autumn months by the appearance of orange/red leaf colours, indicating early symptoms of plant stress. These symptoms are followed by leaf senescence (Figure 10).

Figure 8. Vine weevil with electronic tag for monitoring movement

Figure 9. Vine weevil adults congregated under grooved board

Figure 10. Patches of vine weevil-damaged strawberry plants showing orange/red leaf colours and sensecence

Implications of different crops and production systems

Vine weevil attacks have become more frequent and damaging in recent years as a result of increased soft fruit production under protection, in containers and the widespread use of polythene mulches in soil grown crops.

In terms of crop production, soil-less production in substrate and the use of polythene mulches for soil grown crops have many advantages. Such systems provide warm moist conditions which are ideal for vine weevil larval development and increase the risk of adult survival over the winter. They also offer protection from predatory birds such as pheasant, partridge and some protection from predatory ground beetles, particularly where crops are raised on table tops. For soil grown crops, the mulches also limit opportunities to effectively target control measures at both vine weevil larvae and adults.

Strawberry

Field grown crops

Field grown mainseason varieties are normally retained for two crops but sometimes a third, especially in PYO production. Everbearer varieties are generally grown for one crop but occasionally a second. Where either mainseason or everbearer varieties are kept for these further years, there is more risk of vine weevil damage as populations have had more time to build up.

Potential solutions to problems with field grown crops include:

1. Annual cropping: The shorter cropping time gives vine weevil populations less chance to build up to damaging levels. Growers who reduce their cropping cycles succeed in reducing the level of damage, although there can be economic implications in reducing the number of crops picked from one plantation.
2. High density plantings in the first year of cropping a 60-day crop can help to make up for any loss of fruit in subsequent years after grubbing.

Container production

Many growers now produce both mainseason and everbearer varieties in substrate bags or troughs which are laid on polythene-mulched raised beds or supported on table tops under semi-permanent tunnel structures. Where bags are removed after each crop and replaced with a new set placed on the existing polythene-covered beds, this increases the risk of vine weevil carry over into succeeding crops. Where possible it is best to avoid planting and establishment of such bags during mid-summer (May to July) when adult weevils can easily walk into new plantations. It is also best to avoid re-planting new crops into old bags or substrate in troughs as this will increase the risk of the new crop being infested with vine weevils.

Modular tray and potted planting material

Growers should be aware of the risk of importing vine weevil onto a site when purchasing plant material. This risk has increased in recent years due to the use of modular tray and potted plants. Ideally the propagator should apply entomopathogenic nematodes to the plants before dispatch. However, on arrival, a number of modules should be removed from the trays and the root systems checked carefully for signs of larvae or damage. If larvae are found, the propagator should be alerted. If control measures are necessary, nematodes should be applied to the modules before planting (see Control section below).

Cane and bush fruit

Soil grown crops

These crops often remain in the soil for 10 years or more, and it can be difficult to eradicate vine weevil infestations. To help reduce this problem, growers should restrict the use of polythene mulches (which aid winter survival of weevils and lower predation) to the first few years of plantation establishment.

Container production

Protected raspberry, blackberry and blueberry crops grown in containers are particularly at risk to vine weevil as both the tunnel structure and pots provide favourable conditions for the pest. In the warmer conditions, adults are active for longer than in outdoor crops and may overwinter. Larvae are able to move more easily through the substrate than in field grown soils and can feed on a greater proportion of roots as they are contained within relatively small volumes in the pots. Where crops such as blueberries are kept in containers for a number of years the risk of vine weevil infestation is greater the longer they are kept. However, on the positive side, control measures are easier to apply and are more effective than in field grown crops, and container-grown crops of cane fruit are often retained for only one or two crops giving vine weevil populations less time to build up.

Control – Introduction

There are currently no conventional products approved for use as a drench for the control of vine weevil larvae on soft fruit crops. No products are currently recommended for use as a foliar spray for the control of adult weevils, although some control may be given by those recommended for the control of other pests (See Table 2, located in the wallet at the back of the factsheet). Therefore an Integrated Pest Management (IPM) programme should be planned carefully for effective management of vine weevil. The IPM programme should include cultural and biological control methods together with monitoring and selective use of products for the control of adults. Use of IPM will meet increasing retail and government pressures to reduce the use of chemical control measures. The Sustainable Use Directive (SUD) currently requires that in EU member states, IPM should be used by all professional users of plant protection products, as long as practical and effective methods are available.

Flow charts summarising the thoughts and decisions to be taken when managing and controlling vine weevil in soft fruit crops are presented in Figures 11a and 11b.

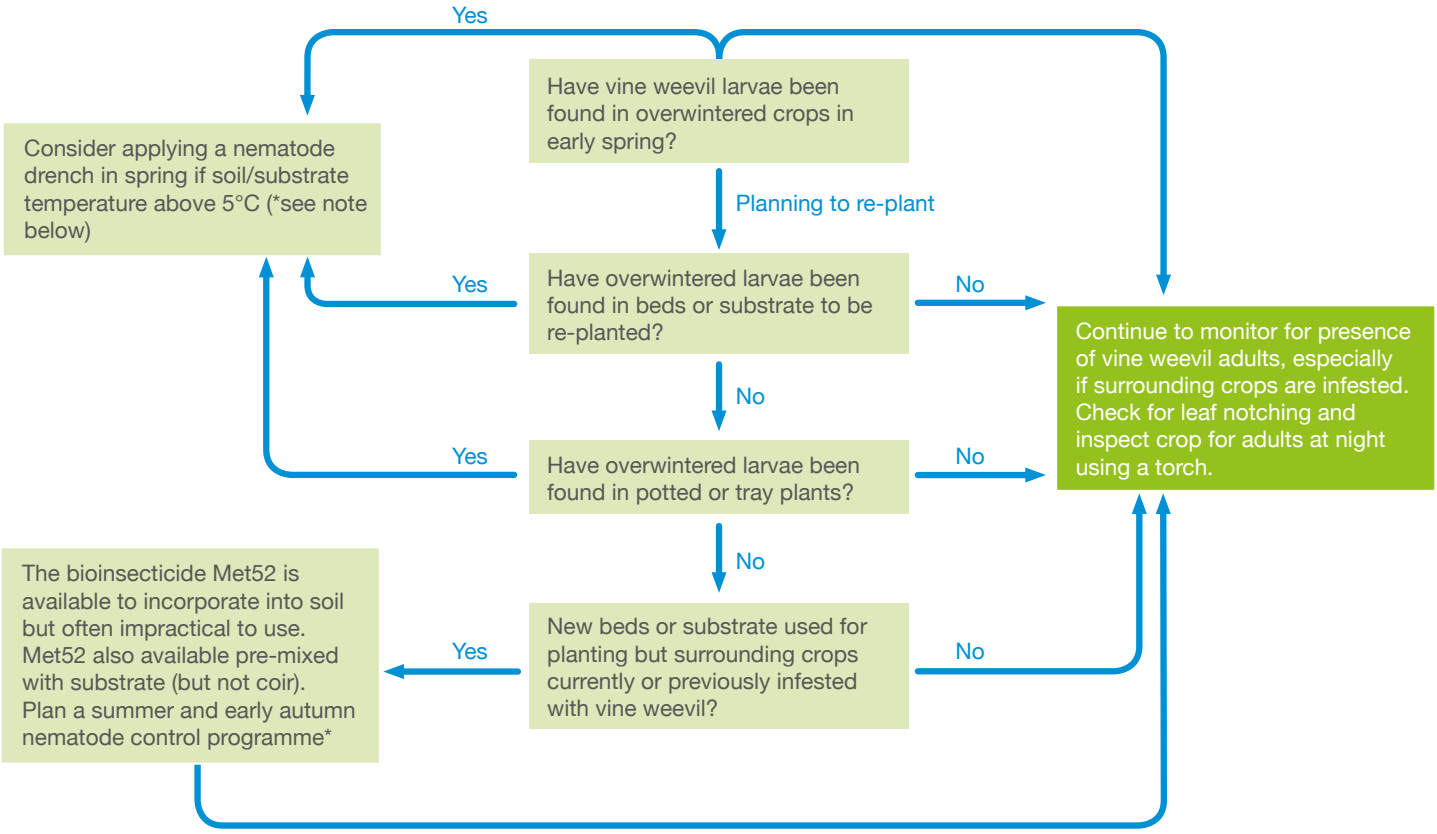

Figure 11a. Decisions in vine weevil management in soft fruit

Early-season (February to April)

*Nematode drenches are most likely to be applied through drip irrigation. The temperature above 5°C may determine the species/product used. Nematode drenches are likely to be more effective in substrate than in soil-grown crops.

Figure 11b. Mid to late season (May to September/October)

*Nematode drenches are most likely to be applied through drip irrigation. The temperature above 5°C may determine the species/product used. Nematode drenches are likely to be more effective in substrate than in soil grown crops.

Cultural control

Vine weevil populations build up on infested plants that have been kept on the farm for more than one season. There are a range of cultural control measures that can be used both to reduce sources of the pest and to limit its spread if a crop becomes infested. Paying close attention to farm hygiene can help to reduce the sources not only of vine weevil but also of other pests and diseases.

Before planting a new crop

- Aim to control vine weevil in older crops (see Biological control section) before any younger neighbouring plantations become infested.
- When establishing a new plantation, where possible find a site isolated from vine weevil-infested crops.
- When planting at a site directly following a crop known to be infested with vine weevil, consider sterilising the site prior to re-planting and pay particular attention to the removal of all trash and debris which could harbour the pest.
- If vine weevil larvae are present in the remains of a previous soil-grown crop, do not replant soon after the previous crop. Plant the following year if possible and cultivate the soil regularly to reduce the root system remaining as a food source for larvae. Cultivation will also help to bring any old plant material to the surface in good time before planting the new crop, to expose the larvae to predators such as birds.
- Remove any container-grown plants from a previous crop that may harbour vine weevil and all old containers (bags, pots and troughs) and crop debris. Dispose of these materials promptly. Old plants and substrate can be chopped and spread onto arable land well away from soft fruit crops. Old containers should preferably be sent for recycling or alternatively to landfill.
- Check a sample of new plants in pots or trays before planting for the presence of vine weevil larvae by knocking them out and searching through the growing media. Also check for any adult vine weevil leaf notching or plants showing symptoms of larval damage to roots such as stunting, wilting or yellow or red leaf discolouration.
- Ascertain what control measures have been used on the new plants for vine weevil management. Ideally pot or tray plants will have been drenched with nematodes by the propagator.

During crop production

- In AHDB Horticulture funded project CP 111 ‘A review of vine weevil knowledge in order to design best-practice IPM protocols suitable for implementation in UK horticulture’, removal of polythene or ground-cover matting mulches on strawberry crops grown on soil beds was reported by growers to considerably reduce severe infestations. However, this is often impractical and the mulches are important for maintaining weed and runner control.
- Table top strawberries can be less susceptible to vine weevil, although adults can climb up table top supports. The use of barrier glue on the table supports helps to prevent this.
- Control weeds at the edges of mulches and around field margins, particularly those that can potentially harbour vine weevil, such as dandelion, dock, knotweeds, mallow, orache, plantain and rosebay willowherb.
- Keep punnets and trays off the ground during picking in affected crops and be vigilant for adults falling or crawling into punnets.

Biological control

Biological control agents available for vine weevil management include entomopathogenic nematodes and the entomopathogenic fungus, *Metarhizium anisopliae* (now renamed *M. brunneum)*, sold as Met52®.

Entomopathogenic nematodes

Entomopathogenic nematode products (microscopic worms) are sold commercially in an inert carrier (Figure 12). When received the nematodes are in a semi-desiccated state but they quickly hydrate and revive when water is added. Once applied to moist growing media or soil, the infective juveniles swim short distances to find vine weevil larvae or pupae, homing in on carbon dioxide or exudates released by weevil-damaged roots. The nematodes cannot swim long distances, so need to be applied to the target area where vine weevil larvae or pupae are located around the roots. Once the juvenile nematodes have found their host they enter its body through natural openings such as the mouth or anus. *Heterorhabditis* species can also penetrate the host insect cuticle using a tooth. Once inside the body, the nematodes release symbiotic bacteria that they carry in their gut. *Steinernema* nematode species carry *Xenorhabdus* species of bacteria and *Heterorhabditis* species carry *Photorhabdus* species of bacteria. These bacteria then multiply within the vine weevil and kill it by septicaemia within a few days. The multiplying bacteria provide suitable conditions inside the vine weevil body for the nematodes to grow into adults and reproduce.

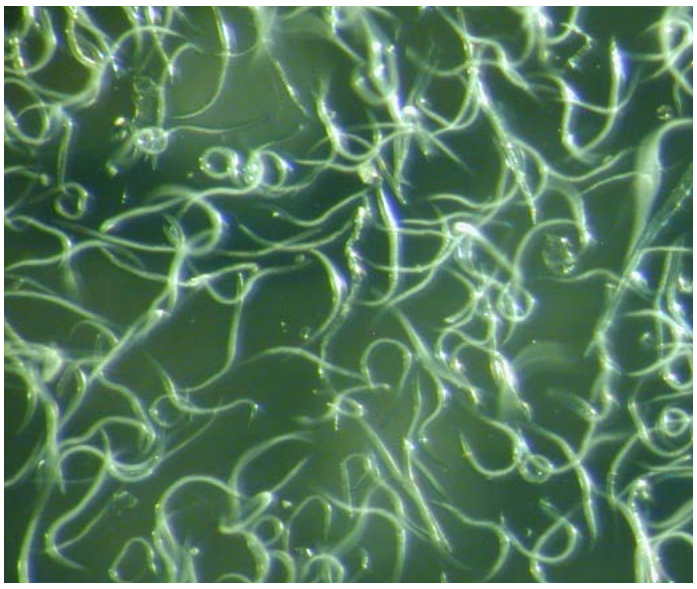

Figure 12. Entomopathogenic nematodes in water seen under a microscope

This leads to a new generation of infective juveniles that leave the disintegrated vine weevil cadaver to find more vine weevil larvae or pupae to infect.

Nematode species and products

In the UK, commercially available nematode products contain *Steinernema kraussei, Heterorhabditis bacteriophora, Heterorhabditis downesi* or a mix of species (Table 1, located in the back wallet of this factsheet). *Steinernema kraussei* products are particularly useful for spring and late autumn applications as this nematode species is effective at soil or growing media temperatures down to 5°C. All nematode species are effective at temperatures up to 28-33°C depending on product (Table 1).

Vine weevil larvae infected with *Heterorhabditis* species turn a red colour (Figure 13) whereas those infected with *Steinernema* species turn a less noticeable yellow-brown colour. However, infected larvae killed by both nematode species disintegrate very quickly after death.

Figure 13. Vine weevil larva infected with *Heterorhabditis bacteriophora* has turned a red colour

Using numbers of live larvae remaining a few weeks after treatment is, therefore, a more reliable guide to the level of control achieved than trying to count infected larvae.

Application timing and frequency

Nematodes should be applied for curative control when larvae are present in the growing media. They will also control weevil pupae. As eggs can be laid for a protracted period, from April (from overwintered adults) or from June (new adults) through to October or November under protection, larvae could be present at any time of year.

Most soft fruit growers apply nematodes during late August and early September when most eggs will have been laid and larvae of various ages will be present, whilst substrate or soil temperatures are suitable for the nematodes to work (Table 1, located in the back wallet of this factsheet). It is a good idea to order nematodes for this application timing in advance to ensure supply. The nematodes only persist in the substrate or soil in sufficient numbers to kill larvae for up to four weeks after application (as long as conditions are suitable). Therefore it is advisable to make a second autumn application, two to four weeks after the first (depending on the timing of the first application and the substrate or soil temperatures), to control larvae hatching from later-laid eggs and to control any that were not killed by the first application. It is very important to select a nematode product that will be effective at substrate or soil temperatures not only at the time of application but also for up to four weeks after application, to allow time for the nematodes to work. A temperature probe should be used to measure substrate or soil temperature. It is also important to apply nematodes to strawberry crops before the larvae have burrowed into the crowns, when it is more difficult for the nematodes to reach the larvae.

The other ‘window’ for nematode application is in April/early May to control overwintered larvae and pupae, but product selection and timing is critical to target applications when substrate temperatures are warm enough for the nematodes but before adults start emerging from pupae. This application time is suitable for spring re-planted strawberry plants.

Some soft fruit growers are now making multiple applications of nematodes through the season using a ‘little and often’ approach and are finding this method more effective than the traditional application timings. In strawberry, some growers are applying reduced rate nematodes every month between May/June and September and in blueberry, applications of reduced rates are being applied every month throughout the year on one farm, due to the crop’s high value and susceptibility to vine weevil damage. Current research in AHDB Horticulture project HNS 195 ‘Improving control of vine weevil in HNS’ has evaluated a ‘little and often’ approach for application of nematodes each month between May/June and October using overhead irrigation systems to apply the nematodes. The method using 40 per cent rate was as effective as two consecutive drenches of nematodes at full rate during September and October when tested in an ADAS research polytunnel and on a commercial hardy nursery stock site.

Application methods

It is essential to follow all the supplier's recommendations carefully for optimum control with nematodes. These include:

Storage before use

- As soon as received, store nematodes in the fridge at the temperature recommended by the supplier (e.g. 2-6°C, 5°C or 4-10°C depending on supplier and product).
- Do not freeze.
- Use by the expiry date printed on the pack.

Application conditions in substrate or soil

- Use of nematodes in substrate-grown crops tends to be more effective than in soil-grown crops due to the smaller root zones of container or bag-grown crops, the comparatively damper conditions due to the more frequent and effective irrigation of substrate crops and to the more open structure of substrates than soils. All these factors help nematodes to move and to find vine weevil larvae.
- Apply to moist substrate or soil and if necessary, irrigate before application. Nematodes need moisture to survive and move.
- If using nematodes in soil-grown strawberry crops, two irrigation lines per bed should be used rather than one, to help wet up the soil in the root zone before application. Nematodes move more easily in lighter soils than heavy soils as long as sufficient moisture is available.
- The 'soil conditioner' Transformer'® is recommended by Bionema for use with their nematode products. This product is claimed to improve the water holding capacity of soil or substrate, thus allowing the nematodes to move and find vine weevil larvae and other insect hosts more effectively. 'Transformer' is also available from other distributors as an individual product so could be used with other nematode products if required.
- Apply when substrate or soil temperatures are within the optimum range for the species being used (Table 1, located in the back wallet of this factsheet) for at least several hours a day and for two to four weeks (depending on product recommendations) after application.

Nematode application rates

- Use the rate of nematodes recommended by the supplier. Most suppliers recommend a number of nematodes per plant for strawberry crops and one supplier (e-nema) recommends higher numbers per plant for blueberries. For other crops, the rate is recommended as numbers per m^2 for use in soil or substrate-grown crops or some suppliers recommend numbers per litre of substrate for container-grown crops.
- Usually the recommended rate for use in soil is higher than that recommended for use in substrate in pots or containers.
- Some growers of strawberry and blueberry crops are using reduced rates of nematodes in a 'little and often' approach rather than using recommended rates at the traditional timings.
- Use the whole pack(s). Do not divide them as nematodes may be unevenly distributed within the pack.

Water application rates

- Once the nematodes have been mixed with water at the recommended rate, apply in the recommended volume of water per m^2. This water volume is specified by some suppliers and not others. Some suppliers recommend a specific water volume per plant rather than per m^2 for use on strawberry crops.
- Some suppliers give recommended volumes of water per pot depending on pot volume and offer details of how many pots of a certain volume can be treated per pack of nematodes.
- As a rule of thumb for application to containers, the total volume of water applied (including that used for nematode application and that used for irrigation afterwards) should be approximately 10% of the pot volume, but this will depend on substrate moisture content prior to application. For example, for a 7-litre pot, a total of 700 ml of water should be applied. Some growers prefer to use higher water volumes (e.g. one third of the pot volume), to ensure that the nematodes reach the vine weevil larvae in the pots. Care should be taken when using higher water volumes to ensure that the drench does not run out of the bottom of the pot.

Using acid, fertilisers and plant protection products with nematodes

- If adding acid to lower water pH, do not add acid directly to the nematode mixing tank. The pH should not be below 4.5 to ensure that nematodes are not harmed by acidified water. Similarly, application of fertilisers together with nematodes should be avoided, especially if this would lower the pH below 4.5.
- A few plant protection products can have harmful effects on nematodes, so check with your supplier for details.
- Do not tank mix with plant protection products or concentrated fertilisers, unless specifically recommended by the supplier (check the supplier's website or contact them for details).

Application through drip irrigation systems

- Growers of most soft fruit crops apply nematodes through the drip or trickle irrigation system as this is much more convenient and less labour-intensive than drenching.
- Check with your supplier that your drip irrigation system is suitable for nematode application.
- Before nematode application, remove filters smaller than 50 mesh (equivalent to 0.3mm) downstream of the injection point to avoid nematode blockages.

- Before nematode application, use a food grade dye to test how long it takes the water to reach the intended area of the field. The dye can also be used to check that all drippers are working and are not blocked.
- It will take longer for the nematodes to reach fields further away from the injection point than nearer fields. Similarly, it will take longer for the nematodes to reach irrigation blocks further from the on/off valves than those nearer the valves.
- If more than one irrigation block is to be treated in the same field, treating individual blocks at a time will give a more uniform application than treating several blocks at a time (e.g. five 3-minute irrigation cycles for five successive blocks, rather than one 15-minute cycle for all five blocks). Start with the valve nearest to the nematode injection point and the block nearest the valve.
- Considering the injection rate, the area to treat and the recommended dose rate, calculate the number of nematode packs and volume of water required in the concentrated nematode mixing tank.
- Make up the concentrated nematode suspension by initially mixing with 1-3 litres of water in the nematode mixing tank to break up the formulation and to rehydrate the nematodes and mix thoroughly to ensure they are well dispersed. Then add the remaining volume of water required. If the suspension is too viscous add an additional known volume of water and adjust the injection rate accordingly.
- Set the injection rate on the dosing unit to the appropriate dilution (normally 1% is suitable for nematode application).
- Inject the nematodes using a suitable dosing unit during the first half of the irrigation cycle. Then run the irrigation system for the second half of the cycle with no nematodes injected, in order to flush the nematodes out of the lines and into the crop. It is important to run the irrigation for long enough (for at least as long as it took for the dyed water to reach the field) to allow the nematodes to flow down each irrigation line and out of the drippers to apply a uniform and accurate dose.
- Consider applying nematodes in the first irrigation of the day so that any subsequent irrigation will help to wash the nematodes out of the lines as quickly as possible, as nematodes drown if left for too long in stagnant water.
- Ensure that the nematode suspension is agitated prior to and during injection into the irrigation lines, either by hand stirring, using a mechanical propeller at low revs or by bubbling using an air pump.
- Delivery of nematodes through replicate drippers can be checked by collecting the suspension into small containers. The help of a supplier or consultant may be needed in order to do this.
- After application, rinse the nematode mixing tank and inject through the system.
- Consider spot treatments with a spray applicator at the ends of the drip lines as fewer nematodes are applied here due to the water 'bouncing' back at the end of the lines.

Drenching using spray application equipment

- As an alternative to using drip irrigation, nematodes can be applied to soft fruit crops as a drench using conventional spray application equipment. For example, drenching is often used on blueberry for effective application to the entire root system in the large containers used, including the central root zone where vine weevil larvae do the most damage and the edges where larvae can also occur. In addition, drenching is used in some strawberry crops (e.g. to tray plants if infested with larvae), or to outdoor planted crops where drip irrigation is not available.
- Unlike drip irrigation which is best applied in the first irrigation of the day, when using conventional spray equipment, apply in the late afternoon or evening to avoid harmful effects of high temperatures and UV light. There is no need to mix the nematodes in the dark but ideally this should be done away from bright sunlight.
- All equipment, regardless of application method, should be cleaned/flushed prior to nematode application, particularly if it has previously been used for a plant protection product that is harmful to nematodes.
- The nematodes must be applied to the root zone where needed as they do not move far in the soil or substrate after application.
- Remove all fine filters in the spray lines and nozzles (i.e. 0.3mm or smaller), to prevent nematode blockages. If you do not know the size of filters they are best removed.
- Use nozzles with apertures of at least 0.5mm or 0.8mm diameter (depending on supplier recommendations) and apply as a medium / coarse spray.
- Do not use high pump pressures (i.e. over 5, 12 or 20 bar - depending on supplier recommendations).
- Empty the whole pack(s) of nematodes into a bucket, rinse the packs with a small volume of water and then add 5-10 litres of water (depending on product recommendations) and stir well.
- Partially fill the sprayer tank with water (5-15°C, 5-25°C or 15-20°C depending on product and supplier).
- Start the agitator and add the nematode suspension to the tank through the sieve. Rinse the bucket well and add the rinsings to the tank.
- Keep the agitator running and add the remaining required volume of water to the tank. Apply immediately for best results and do not leave the nematode suspension longer than four hours before use.
- Keep the nematode suspension agitated throughout the application procedure to prevent the nematodes settling out.

- When applying to strawberry crops, drench each plant individually around the base of the plant and avoid run-off over any polythene around the planting hole.
- If irrigation is available, irrigate immediately after application to wash nematodes off any foliage treated and to help to disperse the nematodes into the substrate or soil. If applying to containers, when irrigating take care not to cause run-off from the tops of the containers. If irrigation is not available, try to apply during rain for uncovered crops.
- Keep the soil or substrate moist for at least two weeks after application.

Monitoring to check nematode efficacy

- Check a few containers or plants in grow-bags before application with nematodes and record how many live vine weevil larvae are present in the growing media. Mark the pots or plants and check again two weeks after application (as long as growing media temperatures are within the recommended range) and record how many are dead or have changed colour to red (if treated with *Heterorhabditis* species, Figure 13) or yellow-brown (if treated with *Steinernema* species). Check again after a further one or two weeks and record numbers of live larvae remaining.

Nematodes for control of adult weevils

Although nematodes are only applied for the control of vine weevil larvae and pupae, they can also kill adult vine weevils. E-nema market a vine weevil trap in Germany for the home-garden market, Nematop® Käfer-Stopp (Weevil-Stop) and these traps are now available in the UK for amateur use. The trap is a small piece of wooden board with grooves on the underside that are filled with a gel containing high numbers of *Steinernema carpocapsae*. The dampened trap is placed on the soil, growing media or ground and adult weevils that take refuge under the traps during the day are killed by the nematodes. In the joint-funded project CP 089, ADAS tested the effiacy of the traps and speed of kill. Half the released weevils were killed by *S. carpocapsae* within 16 days and 92% were killed within 30 days. The weevils were dissected to confirm nematode infection (Figure 14). The traps are currently too expensive for commercial use. Employment of the traps together with a vine weevil attractant is being investigated in hardy nursery stock in AHDB Horticulture-funded project HNS 195. It is possible that this approach may lead to the development of a commercial strategy for using nematodes for control of adult vine weevils.

Entomopathogenic fungi

There is only one entomopathogenic fungus species currently approved for vine weevil control in the UK, *Metarhizium anisopliae* (now renamed *M. brunneum*), which is sold as Met52 Granular Bioinsecticide. This is a granular product formulated on rice grains that have the characteristic green colour of the *Metarhizium* spores. Met52 can be bought pre-mixed in growing media (mainly for use in hardy nursery stock and not available pre-mixed in coir) or as the product for growers to incorporate into substrate or soil before planting any soft fruit crop both under protection and outdoors (Table 2 in the wallet at the back of the factsheet). During mixing, fungal spores break off the rice grains and become distributed through the growing media or soil.

When vine weevil larvae come into contact with them, the spores germinate on their cuticles and the fungus grows inside their bodies and kills them. Young infected larvae decay rapidly after death but older infected larvae can be found in the growing media or soil and can be recognised by the fungal growth on their bodies which is white at first but then turns greyish-green (Figure 15). Met52-treated growing media can also be used as a mulch on certain soft fruit crops (Table 2).

Figure 14. Dead adult vine weevil crushed to reveal nematodes inside the body, acquired from taking refuge in a Nematop® Käfer-Stopp (Weevil-Stop) trap

Figure 15. Vine weevil larvae infected with Met52 turn a grey-green colour

Environmental requirements

- Met52 is most effective at temperatures between 15 and 30°C. Below 15°C the fungus works more slowly and it does not work below 10°C, although the spores will remain viable even down to minus 18°C. The spores will be killed at temperatures above 40°C.
- Treated growing media should be stored in a cool shady place, away from direct sunlight and at temperatures below 30°C.
- Met52 can be used in all types of growing media but use in heavy soil types will reduce efficacy.
- The growing media or soil should not be too wet or too dry.

Application methods, timing and persistence

- It is not practical to mix Met52 into coir blocks. If using Met52 in other growing media it should be used throughout the production cycle (i.e. when potting on into larger pots or planting into bags or containers, the fresh growing media should also be treated).
- The product should be thoroughly incorporated into growing media using the recommended rate and using clean mixing equipment free from pesticide residues. Once mixed the growing media should be used within 30 days.
- When applied by broadcasting to field soil immediately before planting in the spring it should be incorporated into the top 5cm. Met52 should not be applied to soil before autumn planting due to its temperature requirements.
- Met52 can also be applied as a mulch on container-grown top fruit for the control of vine weevil larvae and on blueberry, bilberry, cranberry, Ribes hybrids, Rubus hybrids, Loganberry and table/wine grapes for the control of the ground-dwelling life stages of leatherjackets and midges, when it can give some incidental control of vine weevil (Table 2). Apply as a 5cm mulch in late spring, before adult vine weevils lay their eggs, in order to target larvae hatching from eggs laid into the mulch. Keep the mulch moist to optimise control.
- The product should be applied before vine weevil egg laying occurs, not as a curative treatment.
- Met52 is likely to persist in treated growing media or soil for a year, but will only infect vine weevil larvae in favourable conditions. For example, the product will stop working when temperatures become too cool in the autumn but it will become active again once temperatures rise in the spring. Therefore larvae could become infected with spores in the autumn but they will not die until the spring, by which time plant damage may already have occurred.
- If used pre-planting, Met52 will not give control of vine weevil after the first year's cropping in any soft fruit crops grown for subsequent years.
- The effect of typical fluctuating temperatures on Met52 efficacy is not well understood. This is being investigated in hardy nursery stock in the current AHDB Horticulture-funded project HNS 195.

Monitoring for Met52 efficacy

- Check for live and dead vine weevil larvae in the growing media from April to September and look for symptoms of Met52 infection (Figure 15).
- Presence and efficacy of Met52 in treated growing media can be checked by using fresh mealworms in a simple test. Guidelines are available from Fargro.

Use within an IPM programme

- Met52 should not be relied upon as the sole method for vine weevil control, but should be used as part of an IPM programme for vine weevil management.
- If using in strawberry, use together with nematode application as vine weevil larvae can burrow into the fleshy crowns where they will be protected from Met52 spores in the substrate or soil.
- Monitor all treated crops regularly for weevil larvae, particularly when soil or growing media temperatures drop below 15°C in the autumn and apply a curative drench of nematodes if required, selecting a nematode species and product according to temperature (Table 1).
- As Met52 is a fungus it could be adversely affected by some fungicides used as drenches to the growing media. Check the supplier's recommendations. Further work on the side effects of fungicides on Met52 is being done in AHDB Horticulture-funded project HNS 195.

Natural predators

Naturally-occurring predatory carabid (ground) beetles (Figure 16) and staphylinid (rove) beetles (Figure 17-overleaf) commonly occur in soft fruit fields. In AHDB-funded project SF 15b, gut analysis using a monoclonal antibody technique confirmed that both groups of beetles had predated vine weevil eggs, larvae or adults in strawberry and blackcurrant plantations. Other invertebrate natural enemies of vine weevil include ants, earwigs and both predatory and parasitic wasps. Avoiding the use of broad-spectrum plant protection products will help these natural beetle populations to survive and contribute to vine weevil control.

Figure 16. Carabid beetle adults feeding

Figure 17. Devil's coachhorse with vine weevil larva

Shrews, hedgehogs and various birds will also predate vine weevils. Song Thrush and Skylark will both consume weevils but are not widespread. Pheasant and partridge are more common and can be useful as they tend to scratch and peck around the base of plants where the adults are found. Wild birds can be encouraged by local hedgerow management, and natural and artificial refuges can be provided for hedgehogs.

Commercially available beetles

Defra-funded research (project PS2130) demonstrated that the commercially-available rove beetle, *Atheta* (now renamed *Dalotia coriaria*) that is used in some protected edible and ornamental crops for control of sciarid and shore fly eggs and larvae, will also predate young vine weevil larvae. Subsequent research at Harper Adams University showed that *Dalotia coriaria* will also eat newly laid vine weevil eggs and that they are compatible with Met52 over a 30-day period. Further research would be needed to investigate the potential of *Dalotia* against vine weevil before it could be recommended to growers

Chemical Plant Protection Products

Integrating plant protection products with biological control agents in an IPM programme

A summary of the various components of vine weevil IPM programmes for soft fruit crops can be found in Table 3 (located in the wallet at the back of the factsheet). Within an IPM programme, it is best to use products safest to biological control agents when controlling other pests. Table 2 in the wallet at the back of the factsheet lists those products currently recommended for vine weevil control or which offer some incidental control when used against other pests in soft fruit. Further details of the side effects of plant protection products (PPPs) on biological control agents can be found on several dedicated websites listed in the Further Information section.

When choosing the optimum control products, consult a BASIS qualified advisor and if necessary seek the advice of an IPM consultant, the biological control supplier or the supplier of the PPPs.

Table 1. Currently available nematode species and products for vine weevil control and soil or growing media temperature ranges

Nematode species	Product name	Producer/supplier	Temperature range	Comments
Steinernema kraussei	Nemasys L	BASF	5-30°C	
S. kraussei	Exhibitline sk	Bioline AgroSciences Ltd.	5-30°C	
S. kraussei	Kraussei-System	Biobest	5-30°C	
Steinernema feltiae	Entonem	Koppert	8-33°C	
Heterorhabditis bacteriophora	Exhibitline h	Bioline AgroSciences Ltd.	12-30°C	
H. bacteriophora	Nemasys H	BASF	12-30°C	
H. bacteriophora	Nematop	e-nema	above 12°C for several hrs per day	
H. bacteriophora	Larvanem	Koppert	14-33°C	
H. bacteriophora	NemaTrident-H	Bionema	12-28°C	Recommended with a 'soil conditioner' (Transformer®)
Heterorhabditis downesi	NemaTrident-CT	Bionema	8-28°C	Recommended with a 'soil conditioner' (Transformer®)
A mix of *Steinernema carpocapsae, S. feltiae* and either *H. bacteriophora* or *H. megidis*	SuperNemos	Flowering Plants Ltd.	above 10°C	Marketed for control of a range of insect species in one application e.g. vine weevil larvae, leatherjackets and sciarid fly larvae
A mix of *H. bacteriophora* and *S. feltiae*	NemaTrident-CT Plus	Bionema	8-28°C	Recommended with a 'soil conditioner' (Transformer®)

Table 2. Currently approved plant protection products that are either recommended for vine weevil control or will give some incidental control when used for control of other pests in soft fruit (September 2017).

Product name (examples)	Active ingredient and IRAC code	Insecticide group	Approval status for soft fruit crops range	Application method	Compatibility with biological control agents used against other pests	Comments
Biopesticides recommended for control of vine weevil larvae						
Met52	*Metarhizium anisopliae* (now renamed *M. brunneum)*	Entomopathogenic fungus	On-label for protected and outdoor blackberry, blackcurrant, blueberry, gooseberry, raspberry, redcurrant, strawberry & whitecurrant.	Growing media or soil incorporation pre-planting in spring.	Safe to entomopathogenic nematodes. May reduce survival of other biological controls with a ground-dwelling life stage e.g. *Aphidoletes, Dalotia (Atheta)*.	Needs 15-30°C when vine weevil larvae present.
Met52	*Metarhizium anisopliae* (now renamed *M. brunneum)*	Entomopathogenic fungus	EAMU (1997/2011)	Mulch on container-grown top fruit and on established plants in blueberry, bilberry, cranberry, Ribes hybrids, Rubus hybrids, Logan berry, table and wine grape crops.	Safe to entomopathogenic nematodes. May reduce survival of other biological controls with a ground-dwelling life stage e.g. *Aphidoletes, Dalotia (Atheta)*.	For control of vine weevil larvae in container-grown top fruit. For control of leatherjackets and midges with a ground-dwelling pupal stage in the named soft fruit crops but may give incidental control of vine weevil larvae. Needs 15-30°C when vine weevil larvae present.

Table 2. Currently approved plant protection products that are either recommended for vine weevil control or will give some incidental control when used for control of other pests in soft fruit (September 2017).

Product name (examples)	Active ingredient and IRAC code	Insecticide group	Approval status for soft fruit crops	Application method	Compatibility with biological control agents used for whitefly control*	Comments
Insecticides approved for control of other pests that may give some control of vine weevil adults						
Chess WG	pymetrozine (IRAC code 9B)	Azomethine	EAMUs (1249/2016: protected strawberry and 1248/2016, 1258/2016 and 0862/2017: various protected soft fruit crops).	Foliar spray	Safe to *Neoseiulus cucumeris* & *Encarsia*, slightly harmful to *Aphidius* & *Phytoseiulus*, harmful to *Aphidoletes*.	Research in SF/HNS 112 demonstrated some kill of adult vine weevils. Check EAMUS for all conditions of use including permitted crops and harvest intervals.
Plenum WG	pymetrozine (IRAC code 9B)	Azomethine	EAMUs (1633/2006: outdoor blackberry & raspberry, 1702/2006: various outdoor soft fruit crops).	Foliar spray	Safe to *Neoseiulus cucumeris* & *Encarsia*, slightly harmful to *Aphidius* & *Phytoseiulus*, harmful to *Aphidoletes*.	Same active ingredient as Chess WG which gave some kill of adult vine weevils in SF/HNS 112.
Explicit	indoxacarb (IRAC code 22A)	Oxadiazine	EAMUs (1468/2014: outdoor strawberry, 1369/2013: outdoor & protected raspberry & blackberry and outdoor blueberry).	Foliar spray	Safe to *Neoseiulus cucumeris* & *Phytoseiulus persimilis,* slightly harmful to *Encarsia*, moderately harmful to *Orius* for up to 3 weeks.	Same active ingredient as Steward which gave some kill of adult vine weevils in SF/HNS 112.
Steward	indoxacarb (IRAC code 22A)	Oxadiazine	EAMUs (1031/2014: outdoor strawberry and 0988/2013: outdoor & protected raspberry & blackberry and outdoor blueberry).	Foliar spray	Safe to *Neoseiulus cucumeris* & *Phytoseiulus persimilis,* slightly harmful to *Encarsia*, moderately harmful to *Orius* for up to 3 weeks.	Research in SF/HNS 112 demonstrated some kill of adult vine weevils.
Agrovista Reggae	thiacloprid (IRAC code 4A)	Neonicotinoid	EAMUs (0465/2008: outdoor strawberry, 2033/10: protected strawberry, 0475/2008: outdoor blackberry, raspberry & Rubus hybrids, 0467/2008: protected raspberry & blackberry).	Foliar spay	Moderately harmful to *Aphidius, Encarsia, Neoseiulus cucumeris* and *Phytoseiulus*. Harmful to *Aphidoletes*.	Check EAMUs for all conditions of use including number of applications per crop per year.

Table 2. Currently approved plant protection products that are either recommended for vine weevil control or will give some incidental control when used for control of other pests in soft fruit (September 2017).

Product name (examples)	Active ingredient and IRAC code	Insecticide group	Approval status for soft fruit crops	Application method	Compatibility with biological control agents used for whitefly control*	Comments
Insecticides approved for control of other pests that may give some control of vine weevil adults						
Calypso	thiacloprid (IRAC code 4A)	Neonicotinoid	EAMUs (2131/2014: outdoor strawberry, 2132/2014: protected strawberry).	Foliar spray	Moderately harmful to *Aphidius*, *Encarsia*, *Neoseiulus cucumeris* and *Phytoseiulus*. Harmful to *Aphidoletes*.	Check EAMUs for all conditions of use including number of applications per crop per year.
Bandu	deltamethrin (IRAC code 3)	Pyrethroid	On-label for control of other pests on raspberry. EAMU (1106/2014: outdoor blackberry, 2527/2013: protected & outdoor strawberry).	Foliar spray	Harmful to most biological control agents for up to 12 weeks, incompatible with IPM.	Research in SF/HNS 112 indicated that some vine weevil populations may be resistant to pyrethroids.
Decis	deltamethrin (IRAC code 3)	Pyrethroid	On-label for control of other pests on raspberry. EAMU (0905/2014: outdoor blackberry, 1643/2013: protected & outdoor strawberry).	Foliar spray	Harmful to most biological control agents for up to 12 weeks, incompatible with IPM.	Research in SF/HNS 112 indicated that some vine weevil populations may be resistant to pyrethroids.
Hallmark with Zeon technology	lambda-cyhalothrin (IRAC code 3)	Pyrethroid	EAMUs (1705/2011: outdoor & protected strawberry, 0728/2006: outdoor raspberry, blackberry & Rubus hybrids).	Foliar spray	Harmful to most biological control agents for up to 12 weeks, incompatible with IPM.	Research in SF/HNS 112 indicated that some vine weevil populations may be resistant to pyrethroids.
Pyrethrum 5 EC, Spruzit	pyrethrins (IRAC code 3)	Pyrethrins	On-label for control of other pests on all outdoor and protected crops.	Foliar spay	Harmful to most foliar-dwelling biological control agents, but short persistence.	Research in SF/HNS 112 indicated that some vine weevil populations may be resistant to pyrethroids and therefore could also be resistant to pyrethrins.

Footnotes on reverse.

The information in this table has been collated using information from the Health and Safety Executive (HSE) website (www.pesticides.gov.uk) and from suppliers' labels and product technical information. Important - regular changes occur in the approval status of plant protection products, arising from changes in the legislation or for other reasons. For the most up to date information, please check the HSE website or with a professional supplier or BASIS-qualified consultant, as information could have changed since this factsheet was produced.

EAMU - Extension of Authorisation for minor use.

Growers must hold a paper or electronic copy of an EAMU before using any product under the EAMU arrangements. Any use of a plant protection product with an EAMU is at grower's own risk.

Always follow approved label or EAMU recommendations, including rate of use, maximum number of applications per crop or year, harvest interval and where crop safety information is not available, test the product on a small number of plants to determine crop safety prior to widespread commercial use.

If in doubt about which products are permissible on soft fruit crops or how to use them correctly, seek advice from a BASIS-qualified consultant with expertise in soft fruit production.

Full details of compatibility of plant protection products with biological control agents are available from biological control suppliers or consultants. See the following websites: www.biobest.be and www.koppert.com.

'Safe': kills<25% of the biological control agents; 'slightly harmful': kills 25-50%; 'moderately harmful': kills 50-75%; 'harmful': kills >75%.

Table 3. Summary of components of a vine weevil Integrated Pest Management programme for soft fruit crops

IPM component	Product name
Monitoring	Check around roots for larvae March-November, check again 2-4 weeks after nematode application to guide repeat applications.
Cultural control	Dispose of badly infested plants, substrate and containers, keep weeds controlled and maintain good farm hygiene. Site new plantations away from vine weevil-infested crops. Consider using barrier glue on table-top supports. Keep punnets and trays off the ground during picking in known infested crops.
Entomopathogenic nematodes - timing	In substrate crops, apply by drip-irrigation in April/May if live overwintered larvae found, repeat in August-September (2 applications may be needed during this period). Or consider the 'little and often' approach (reduced rates applied monthly May to September). This has been tested and shown to be as effective as two full rate drenches.
Entomopathogenic nematodes - temperatures	*Steinernema kraussei* (Nemasys L, Exhibitline sk) 5-30°C *Heterorhabditis bacteriophora* (Nemasys H, Exhibitline h) 12-30°C *H. bacteriophora* (Larvanem) 14-33°C *H. bacteriophora* (Nematop) minimum 12°C Mix of *Steinernema carpocapsae*, *S. feltiae* and either *H. bacteriophora* or *H. megidis* (SuperNemos) minimum 10°C *Heterorhabditis downesi* (Nematrident CT) 8-28°C *Steinernema feltiae* (Entonem) 8-33°C
Met52	Minimum temperature for activity against larvae 15°C. Consider EAMU 1997/2011 for use as a mulch e.g. to plants in large pots, in the spring before adults start laying eggs.
Chemical control - adults	Consider foliar spray(s) against adults in April-May (overwintered adults) or June/July (new adults). Chess WG (EAMU 0862/2017) for outdoor, uncropped soft fruit where a 1-year harvest interval is possible i.e. plants in propagation and Steward (EAMU 1031/2014) for use on outdoor strawberry up to BBCH 91 (most flowers with petals forming hollow balls) or post-harvest from BBCH 59 (beginning of axillary bud formation) are more IPM-compatible than other pesticides and showed promise in HDC project SF HNS 112. (The lower rate for Chess on other EAMUs has not been tested).
Chemical control - larvae	No current options.

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Further information

AHDB Horticulture factsheets and publications

- AHDB Factsheet 18/10. Host plant range of vine weevil.
- AHDB Factsheet 24/16. Vine weevil control in hardy nursery stock.
- AHDB Factsheet 07/11. Beetle and weevil pests of cane fruit crops.
- AHDB Grower guide. Biocontrol in soft fruit (2012).

AHDB Horticulture grower summaries and reports

- CP 111 - A review of vine weevil knowledge in order to design best-practice IPM protocols suitable for implementation in UK horticulture (2014).
- SF HNS 127 - Characterising vine weevil aggregation pheromone for use in traps at soft fruit and nursery sites (2012).
- SF HNS 112 - Evaluation of insecticides for control of adult vine weevil under controlled conditions (2012).
- SF 103 - Evaluation of *Metarhizium anisopliae* for control of black vine weevil in field grown strawberries (2011).
- SF 015b - Predation on vine weevil in soft fruit plantations (1997).

Information on the side effects of crop protection products on biological control agents for tarsonemid mite

Useful information can be found at the following websites:

- **www.biobestgroup.com/en/side-effect-manual**
- **www.koppert.com/side-effects**
- **www.biolineagrosciences.com/products (Searchable compatibility database on the downloadable Bioline App)**

Other publications

A practical IPM Guide to controlling vine weevil on ornamental nurseries. Available from Fargro or on their website, **Fargro.co.uk**

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