AHDB HORTICULTURE

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# Pest insects infesting carrot and other Apiaceous crops

Carrot and related Apiaceous crops such as parsnip, celeriac and celery may be infested by a relatively small number of damaging pest insect species that can reduce both quality and yield. This factsheet focuses on the pest insects infesting carrot. However, the insects described may also be pests of related crops such as parsnip, celeriac and celery. The factsheet does not cover nematodes or slugs.

Figure 1. Carrot fly damage to carrot roots

## Action points

### Carrot fly

- Use the carrot fly forecast to indicate when adult flies of each generation are likely to emerge and when the application of insecticide sprays is likely to be most effective.
- Check whether an insecticide spray treatment is able to kill adults or larvae or both stages. To maximise the 'knockdown' effect of insecticide sprays that target adults, they should be applied between 4–6pm on warm days, as this is when most female flies are in the crop.
- Where possible, isolate new crops from possible sources of infestation (older crops), ideally using a separation distance of >1km.

### Aphids

- Use the willow-carrot aphid forecast to indicate the likely time of migration of winged aphids into crops.
- Use suction trap records to indicate when all species of pest aphid are on the wing.
- Monitor crops closely.
- Use the most effective aphicide treatments available, taking account of their effects on natural enemies and be aware of potential instances of insecticide resistance.

### Cutworms

- Use pheromone traps to indicate when turnip moths are flying and laying eggs.
- Use a cutworm forecast to estimate the risk of damage to susceptible crops.
- Consider using irrigation to manage cutworm infestations if the risk is very high (very dry conditions).

## Introduction

The main pests of carrot are carrot fly (*Psila rosae*) (Figure 2), several species of aphid (*Cavariella aegopodii*, *Cavariella pastinacae*, *Cavariella theobaldi*, *Myzus persicae*) and larvae of the turnip moth (*Agrotis segetum*) (cutworms). Additional specific pests of celery include celery fly (*Euleia heraclei*) and mirid bugs (particularly *Orthops campestris*).

If unmanaged, carrot fly infestations can damage well over 50% of the crop, and viruses transmitted by aphids have been shown to reduce yield by 50% (FV 445).

As ‘cold-blooded’ organisms, the rate at which these pest insects complete their life cycles is driven by the temperature of their surroundings and they will develop more rapidly when the weather is warm. This means they will become active earlier, following a warm spring and that they are usually active earlier in the south of the UK than in the north.

The life cycles of these pests are very different but there are periods when more than one species is active and so, consequently, control programmes should be planned to take this into account.

Figure 2. Adult carrot fly

Figure 3. Adult carrot flies on a sticky trap

## Carrot fly (*Psila rosae*)

The carrot fly is a pest of carrot, parsnip, celery, celeriac and parsley.

### Life cycle

First generation adult carrot flies (Figures 2 and 3) emerge from pupae from late April through to early June and the timing of emergence will depend on temperatures in the spring. Newly emerged carrot flies feed and mate and there is a period of several days before they lay their eggs. The eggs are laid in the soil close to the base of a carrot plant and the newly hatched larvae move through the soil to the root system. At first, the larvae feed on the lateral roots but then they tunnel into the tap root. When fully grown, the larvae pupate and a second generation of flies emerges from these pupae in mid-July to August and lays eggs. Depending on weather conditions, the eggs laid at the beginning of the second generation may be able to develop into a third generation of adults which emerge in early autumn. Most second generation eggs do not reach the adult stage and, of these, some reach the pupal stage by the start of winter, while the remainder continue to feed on overwintered carrots until they form pupae in the spring.

### Damage

If carrot fly larvae attack carrot seedlings, they are likely to kill them (Figure 4). Once the tap root has started to develop, damage is caused by the larvae tunnelling into the root to feed (Figure 5).

Figure 4. Carrot seedlings wilting due to feeding by carrot fly larvae

Figure 5. Carrot fly damage to parsnip roots

Research has shown that most damage to overwintering carrots results from larvae that hatch from eggs laid in late July/early August at the beginning of the second fly generation. Unless good control is achieved at this time, it is impossible to prevent damage on carrot crops increasing during the winter months.

In years when there is a third generation, carrot fly activity can extend over many weeks and viable eggs can be laid. Intensive sampling of first instar larvae was done at Wellesbourne during 1995–1998 inclusive (unpublished data, Julia Vincent). The last of the first instar larvae of the year were found between 25 September and 10 October (mean 1 October), before third-generation flies had emerged, indicating that the third generation did not contribute to the overwintering population of larvae. This was confirmed by experiments at four locations from South West England to Central Scotland (FV 13d). At the time, there seemed to be little risk of damage from third-generation carrot fly in most regions of the UK. However, that was 20 years ago and, on average, the weather has become warmer – by approximately 0.4°C. Thus, in very warm years, there may now be a risk of some egg hatch and larval development by the progeny of third-generation flies in crops grown in the south of the country. Further climate change may increase this risk. The carrot fly forecast can be used to indicate the risk of damage due to third-generation flies.

## Monitoring and forecasting

Adult carrot flies can be captured on orange sticky traps and this is a way of monitoring adult numbers in susceptible crops. If traps are angled at 45° to the vertical, they become very selective for carrot flies, which prefer to land on the lower surface of such traps (Figure 6).

Figure 6. Orange sticky trap angled at 45°

Treatment thresholds, to indicate whether a treatment is necessary or whether the pest population is too low to warrant treatment, have been used in other countries and are based on the numbers of carrot flies trapped per day or per week. In principle, for such a system to be effective, there must be a good relationship between the numbers of flies trapped and the amount of damage the crop would suffer if left untreated. A reliable relationship has not been established. Trap placement to assess field populations accurately would also be critical since studies have shown that carrot fly numbers and subsequent damage are highest close to field margins and that fly numbers decrease quite rapidly over a short distance into the crop. Sticky traps should be deployed taking this into account.

The timing of the various stages in the carrot fly life cycle can be predicted using a computer program developed with funding from Defra and AHDB. The output from this program is currently available as part of the AHDB Pest Bulletin, which is hosted on the Syngenta UK website (Figure 7). The forecast indicates when flies of each generation will emerge from pupae and when they will lay eggs.

## Techniques for reducing the overall level of carrot fly attack

Partial levels of resistance to carrot fly are claimed for carrot varieties such as Flyaway and Resistafly, but these varieties are not grown commercially for other reasons. The most resistant varieties support about 50% of the insects and have about 50% of the damage compared with a very susceptible variety. These levels of resistance are too low to provide adequate carrot fly control on their own.

When carrots are first grown on land remote from areas where they have been grown previously, carrot fly is unlikely to cause a problem until numbers have built up. Since, in contrast to many pest insects, adult carrot flies move relatively short distances, there is the opportunity to develop management strategies based on the isolation of new crops from sources of carrot fly. Numbers can be kept low, particularly if early and late crops are well separated to break the sequence of host plants in the pest's life cycle. Research at Wellesbourne showed that relatively few carrot flies moved more than 1km from a previously infested crop and that numbers declined steadily (and predictably) with increasing distance from the 'source' of carrot fly (Finch & Collier, 2004).

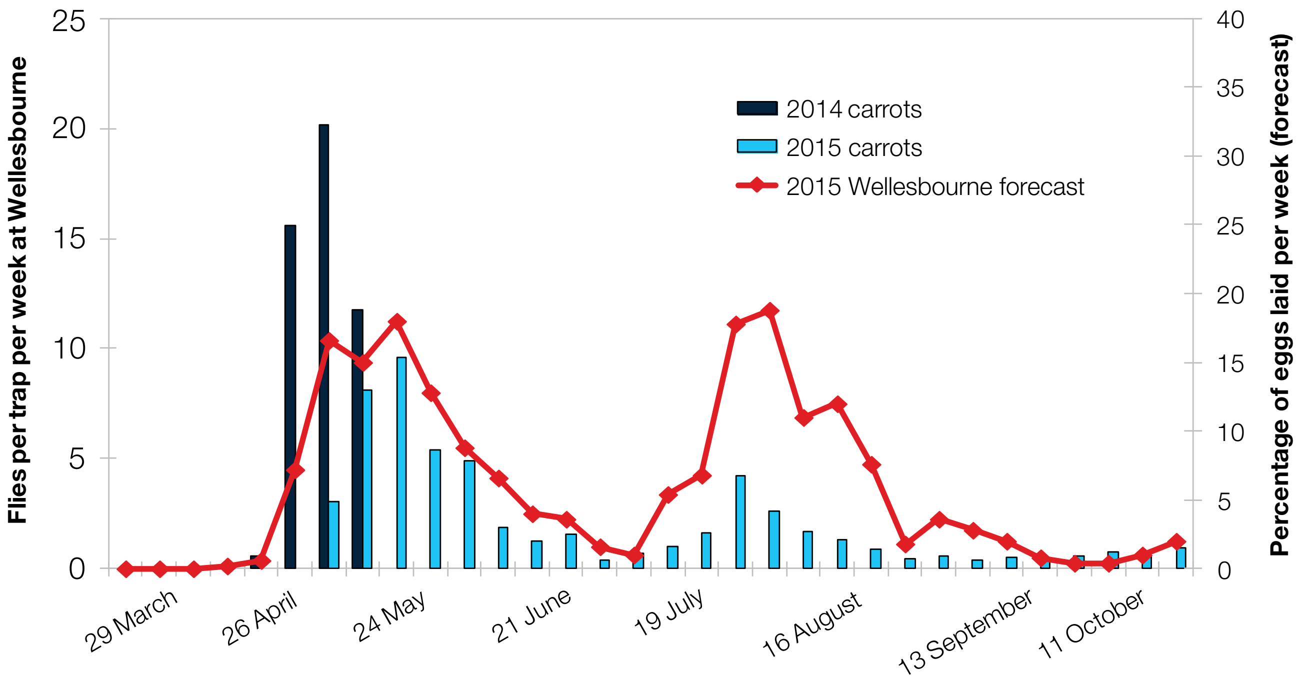


Figure 7. Comparison of observed (trap captures) and forecast carrot fly activity in 2015 at Wellesbourne

Susceptibility to attack varies with sowing date of the crop. Crops that emerge before mid-May are available to first-generation adults for egg laying. This may increase the level of second-generation damage; since adults emerging from the first generation are likely to remain in the vicinity of the crop.

Woven (eg fine mesh netting – mesh sizes specified by suppliers) or non-woven covers (fleeces) can be used to prevent carrot fly attack. The covers can be applied at sowing or later, but must be applied before the flies start to lay eggs. Provided they are applied at the right time, the mesh size is sufficiently small and they stay intact, crop covers exclude all carrot fly. If covers are not applied until the start of the second generation, then first-generation carrot fly must be controlled very effectively with insecticides, otherwise the use of covers may exacerbate the problem. The downside of crop covers is their management, cost and potential effects on disease and weed control, and on yield. Their effects on carrot yields have not been evaluated in the UK.

Early lifting of the entire crop cuts short development of second-generation carrot fly damage and prevents the carryover of large numbers of carrot fly larvae from one year to the next. The carrot fly forecast model has been adapted to produce predictions of when damage symptoms will appear in carrot crops.

The use of vertical fences (up to 2m high) to prevent colonisation by carrot fly has been investigated at Wellesbourne (Figure 8) and elsewhere. However, although these reduced the size of carrot fly infestations they did not exclude all flies (FV 312).

Figure 8. AHDB-funded trial at Wellesbourne on physical barriers to exclude carrot fly (FV 312)

Figure 9. Carrot foliage heavily infested with aphids

## Aphids

Several species of aphid may transmit viruses to carrot (Figure 9). Infection with viruses can produce a range of symptoms in the foliage, which can affect photosynthesis and, thus, have the potential to lower yield. A range of root symptoms such as misshapen roots, stunting, and root browning (necrosis) have been associated with virus infections (see factsheet 07/16 Virus diseases of carrots, for more information on these viruses). Large infestations of aphids may also reduce crop growth and subsequent yield.

## Willow-carrot aphid (*Cavariella aegopodii*)

### Life cycle

This species overwinters mainly as eggs on willow trees and these generally hatch in February to March. The aphids pass through one or two generations on the willow. Winged forms (Figure 9) are produced later and migrate to carrot and other hosts over a five to six-week period. Willow-carrot aphid may also be present as adult or immature stages on carrot crops throughout the winter. These mobile stages are capable of producing spring colonies rapidly, with winged forms potentially arising earlier than those developing on willow trees.

### Damage

This species transmits several viruses to carrot (see factsheet 07/16 Virus diseases of carrots, for more information on these viruses). Large infestations of aphids may also reduce crop growth and subsequent yield. This species infests carrot, parsnip and celery.

### Monitoring and forecasting

Willow-carrot aphids are captured in the network of suction traps operated by the Rothamsted Insect Survey. They can also be captured in yellow water traps and commercial monitoring services using water traps are available.

A forecast has been developed at the University of Warwick and this is based on accumulated day-degrees (D°) from 1 February (base 4.4°C). Information from the Rothamsted Suction trap captures at Wellesbourne and Kirton was used to estimate the mean number of D° from 1 February until the first aphid of the year is caught in a suction trap (the start of the migration to carrot). This is after approximately 360D°. The output from this program is currently available as part of the AHDB Pest Bulletin which is hosted on the Syngenta UK website.

## Parsnip aphids (*Cavariella pastinacae* and *Cavariella theobaldi*)

### Life cycle

These species infest carrot and parsnip and both overwinter on willow.

## Damage

It is possible that two species of parsnip aphid also transmit viruses to carrot and thereby reduce yield (see factsheet 07/16 Virus diseases of carrots). These are *Cavariella pastinacae* and *Cavariella theobaldi*.

## Monitoring and forecasting

These aphids are captured in the network of suction traps operated by the Rothamsted Insect Survey. Because they have similar life cycles to *C. aegopodii* there is the possibility of developing a simple day-degree forecast.

**These graphs show that *Cavariella pastinacae* and *Cavariella theobaldi* migrate later than *Cavariella aegopodii* overall.**

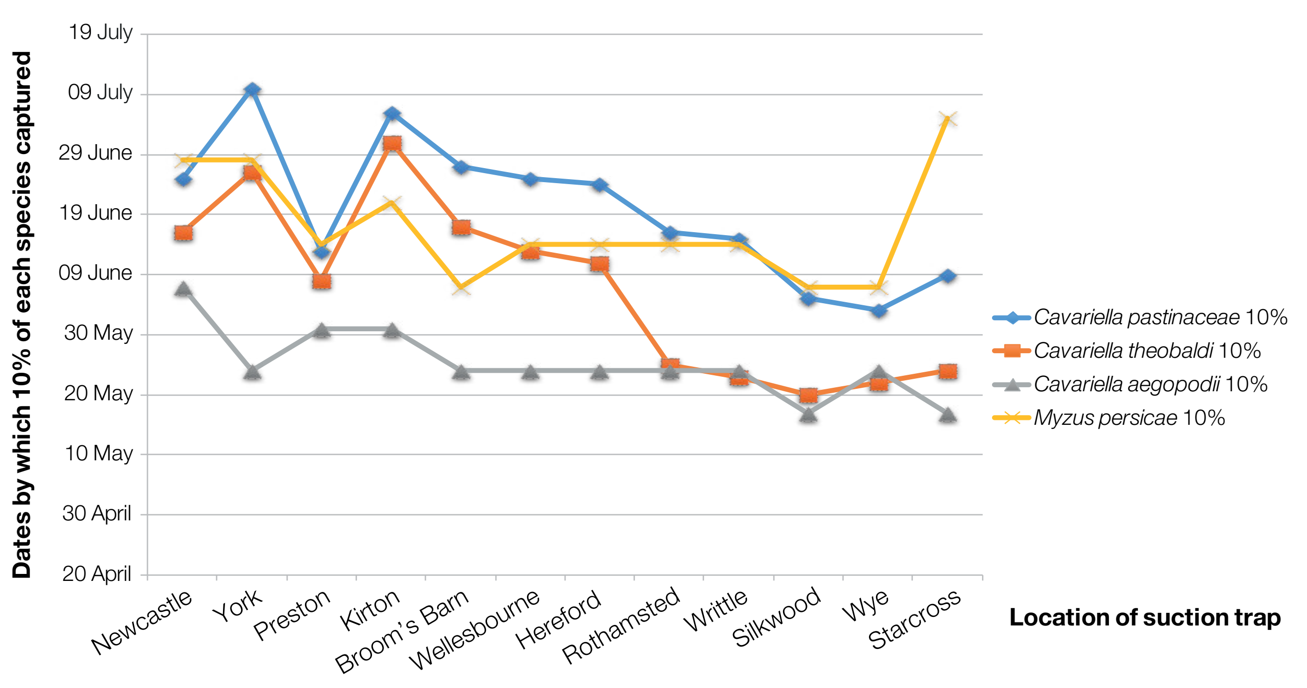


Figure 10. Dates by which 10% of each species of aphid were captured in each suction trap (start of migration) in 2015

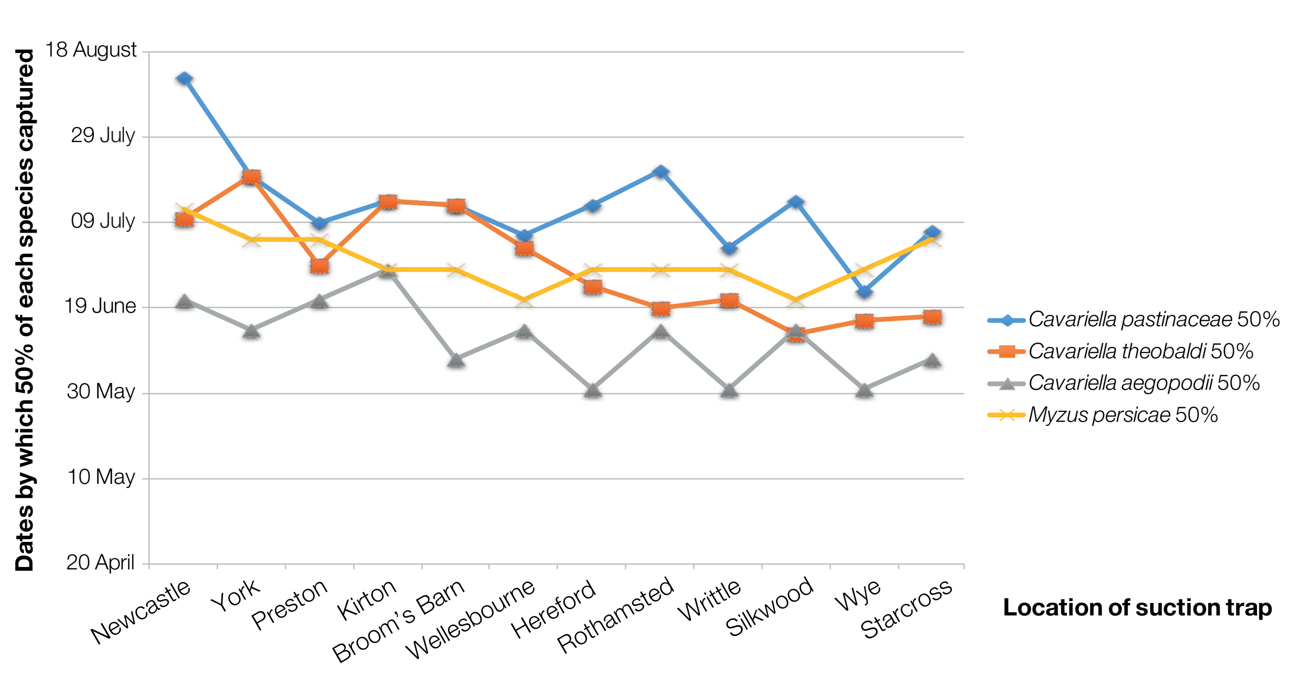


Figure 11. Dates by which 50% of each species of aphid were captured in each suction trap (mid-point of migration) in 2015

## Peach-potato aphid (*Myzus persicae*)

### Life cycle

This species has a very wide range of hosts, including oilseed rape, potato, sugar beet, vegetable Brassicas and lettuce. It overwinters as adult or immature stages on oilseed rape, vegetable Brassicas and weed species.

### Damage

The peach-potato aphid may also transmit viruses to carrot (see factsheet 07/16 Virus diseases of carrots).

### Monitoring and forecasting

These aphids are captured in the network of suction traps operated by the Rothamsted Insect Survey. In early March, the Rothamsted Insect Survey produces a forecast of the timing of the migration and the likely relative abundance of peach-potato aphids in the early summer. This is based on winter temperatures.

## Other pests of Apiaceous crops

## Turnip moth (*Agrotis segetum*)

### Life cycle

'Cutworm' is the name given to caterpillars of certain Noctuid moths, in particular those of the Turnip moth cutworm (*Agrotis segetum*) (Figure 12). The adult moths lay eggs on plants or on pieces of litter and debris in the soil, usually from the end of May or early June. These hatch in around 8–24 days, depending on temperature. The young caterpillars seek out and feed on the aerial parts of plants. In a further 10–20 days, again depending on temperature, the caterpillars go through their second moult, becoming 'third instar' caterpillars. It is at this point that they adopt the cutworm habit, becoming subterranean.

Figure 12. Caterpillars (larvae) of the turnip moth (*Agrotis segetum*)

Unhatched turnip moth eggs and the older, subterranean cutworms are largely invulnerable to the effects of the weather and insecticides. The two early caterpillar instars differ, however. If there is substantial rainfall (defined as 10mm or more of rain falling in showers of moderate intensity over a 24-hour period) while these caterpillars are feeding above ground, this causes high mortality. There is a second generation of turnip moths towards the south of the UK but the caterpillars from this generation are not considered to be a threat to crops.

### Damage

The name 'cutworm' derives from the habit of the older caterpillars feeding underground, damaging plant roots and stems, sometimes so badly that the plant collapses. Crops differ in their susceptibility to cutworm damage. Moderately susceptible crops include carrot, celery and parsnip.

### Monitoring and forecasting

Pheromone traps can be used to monitor numbers of male turnip moths. It is assumed that female moths are laying eggs during the period when male moths are captured. Data from trap captures in 2005–2007 at Wellesbourne were used to estimate a day-degree (D°) sum for the start of flight activity. This was 340D° above a base of 7°C from 1 January. The cutworm model is a computer program that uses weather data to predict the rate of development of turnip moth eggs and caterpillars. It also predicts the level of rain-induced mortality among the early-instar caterpillars. The cutworm model published by Bowden *et al* (1983) has been programmed into the MORPH decision-support software and can be used to produce cutworm forecasts, with the weather data used to produce the carrot fly forecasts.

## Celery fly (*Euleia heraclei*)

### Life cycle

The first generation of adults emerges from overwintering pupae in late April to June depending on weather conditions. After mating, the females lay eggs, which hatch in 1–2 weeks and the larval stage lasts a further 2–3 weeks before pupae are formed. A second generation of adults emerges from July onwards and there may be a third generation in the autumn.

### Damage

The celery fly infests celery, parsley and parsnip crops. During egg-laying, female flies puncture the foliage, causing small brown marks. However, the larvae are the most damaging stage as they burrow in the leaves causing large, pale blotches which soon dry up and become brown and papery. Very severe attacks reduce plant vigour.

### Monitoring and forecasting

No methods of monitoring and forecasting have been developed yet.

## Mirid bugs (capsids)

### Life cycle

Sampling in FV 441 has confirmed that *Orthops campestris* is the main species causing damage.

*Orthops campestris* overwinters as an adult and is able to complete its life cycle on Apiaceous weeds (eg wild parsnip, wild carrot). In 2015, where monitoring started in January, adults became more active in mid-April and the first nymphs were found in mid-May. It seems unlikely that this species completes just a single generation in the UK and the data from 2015 suggest there are two generations.

### Damage

Feeding by adults and nymphs on the stems and shoots causes distortion and damage to celery plants (Figure 13).

### Monitoring and forecasting

Approaches to monitoring and forecasting were investigated in FV 441. Adults and nymphs infesting Apiaceous weeds can be sampled by beating the foliage onto a tray. Adults can be captured on the sticky traps used to monitor carrot fly.

Figure 13. Celery plant damaged by mirid bugs

### Techniques for reducing the overall level of infestation

As *Orthops campestris* is able to complete its life cycle on Apiaceous weeds, management of such species in the vicinity of crops may reduce levels of infestation. In organic crops, control is reliant on the use of mesh covers, which work well if applied at the right time and they are well sealed. However, the presence of the covers may exacerbate infection by pathogens such as celery late blight, *Septoria apiicola*, and reduce crop quality.

## Acknowledgements

All images, figures and diagrams are courtesy and copyright of Warwick Crop Centre.

## Further information

### AHDB publications

AHDB Horticulture factsheet 07/16 'Virus diseases of carrots'.

### AHDB project reports

FV 13d – Carrots and parsnips: evaluation of insecticides for control of carrot fly.

FV 312 – Integrated control of carrot pests.

FV 382b – Carrots: The Epidemiology of Carrot yellow leaf virus (CYLV) – the development of a decision support system for the management of carrot viruses in the UK.

FV 375 – Novel strategies for pest control in field vegetable crops.

FV 414 – Carrots: Optimising carrot fly control using pyrethroids and Coragen.

FV 445 – Carrots: Optimising control of willow-carrot aphid and carrot fly.

### Other useful information

Finch, S. & Collier, R.H. (2004). A simple method – based on the carrot fly – for studying the movement of pest insects. Entomologia experimentalis et applicata, 110, 201–205.

Collier, R.H. & Finch, S. (2009). A review of research to address carrot fly (Psila rosae) control in the UK. Bulletin OEPP/EPPO Bulletin 39, 121–127.

Bowden, J., Cochrane, J., Emmett, B. J., Minall, T. E. & Sherlock, P. L. (1983). A survey of cutworm attacks in England and Wales, and a descriptive population model for Agrotis segetum (Lepidoptera: Noctuidae). Annals of Applied Biology 102, 29–47.

Rothamsted Insect Survey website
rothamsted.ac.uk/insect-survey

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**Table 1. Activity of insecticides approved on carrot (2017). The table shows where insecticides have on-label or off-label (EAMU) approval and also gives details of AHDB projects where efficacy has been shown against one or more species (although the dose may not have been exactly the same as that approved eventually). It also indicates where insecticide resistance has been established in some UK populations of the pest**

| Chemical sub-group or exemplifying active ingredient | Active ingredient | Application method | Carrot fly | Aphids | Cutworm |
|---|---|---|---|---|---|
| Carbamate | Pirimicarb<br>Use of Pirimicarb on carrot will expire on 31 July 2017 | Spray | **No efficacy** | Label target<br>FV 312<br>FV 375<br>(resistance in *M. persicae*) | **No efficacy** |
| Diamides | Chlorantraniliprole | Spray | Label target<br>FV 312<br>FV 375<br>FV 414<br>FV 445 | FV 375 | Approved – no specific efficacy data |
| Neonicotinoids | Thiacloprid | Spray | **No efficacy** | Label target<br>FV 312<br>FV 375<br>SCEPTRE (2011) | **No efficacy** |
| Neonicotinoids | Thiamethoxam | Seed treatment | FV 312<br>FV 445 | Label target<br>FV 312<br>FV 445 | **No efficacy** |
| Pyrethrins | | Spray | Label target | Label target<br>(resistance in *M. persicae*) | Label target |
| Pyrethroid | Cypermethrin<br>Deltamethrin<br>Lambda-cyhalothrin | Spray | Label target<br>FV 13d<br>FV 312<br>FV 375<br>FV 414<br>FV 445 | (resistance in *M. persicae*) | Label target |
| Pyrethroid | Tefluthrin | Seed treatment | Label target<br>FV 312 | **No efficacy** | **No efficacy** |
| Tetronic and Tetramic acid derivatives | Spirotetramat | Spray | **No efficacy** | Label target<br>FV 312<br>FV 375<br>SCEPTRE (2011) | **No efficacy** |
| Biopesticide | Garlic | Spray | Approved – no specific efficacy data | Approved – no specific efficacy data | Approved – no specific efficacy data |
| Biopesticide | Garlic | Granules | Approved – no specific efficacy data | Approved – no specific efficacy data | Approved – no specific efficacy data |
| Biopesticide | Natural plant extracts | Spray | Approved – no specific efficacy data | Approved – no specific efficacy data | Approved – no specific efficacy data |
| Biopesticide | Citrus fruit extract | Spray | Approved – no specific efficacy data | Approved – no specific efficacy data | Approved – no specific efficacy data |

*This factsheet includes information available on the Health and Safety Executive (HSE) website (pesticides.gov.uk), on product labels and in supplier technical leaflets. Please check the HSE website or with an appropriate adviser before using the information as regulations may have changed.*

***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. Anyone using a plant protection product via an EAMU should follow EAMU (or label) recommendations. Use is carried out at the grower's own risk. If specific crop safety information is not available, consider undertaking small-scale tests and/or obtain professional advice before widespread commercial use.*

*If in doubt about which products are permissible, or how to use them correctly, seek advice from a BASIS-qualified consultant.*

*Details of compatibility of plant protection products with biological control agents are available from biological control suppliers or IPM consultants.*

## Insecticidal control

### Carrot fly

Since the mid-late 1990s, carrot fly has been controlled in the UK with pyrethroid insecticides, applied either as seed treatments (tefluthrin) or foliar sprays (lambda-cyhalothrin, deltamethrin). Foliar sprays of lambda-cyhalothrin, in particular, have been extremely effective. In many areas, carrot fly populations have declined considerably, although growers continue to be vigilant in applying insecticide treatments. However, complete reliance on insecticides from one chemical group may not be a sustainable strategy for pest control. There is a significant risk of selecting for individuals resistant to pyrethroids, leading to reduced efficacy and, ultimately, control failure if the selection pressure is sufficiently high. However, limited assessments made in 2005 have indicated that carrot flies (at least from Wellesbourne, UK) were fully susceptible to lambda-cyhalothrin at concentrations much lower than the recommended field rate and the good levels of carrot fly control achieved in most insecticide-treated crops would support this.

Pyrethroid sprays are effective only against adult carrot fly but ineffective against carrot fly larvae in the soil. Three pyrethroid insecticides were evaluated in the UK and, of these, lambda-cyhalothrin was the most effective, followed by deltamethrin and then cypermethrin (FV 13d). Research indicated that, because they killed adult flies rather than larvae, the first spray should be applied close to first emergence. Lambda-cyhalothrin sprays applied one week before forecast 10% (first) egg-laying gave better carrot fly control than when the first insecticide spray was triggered by the first capture of flies on sticky traps.

It is important to remember that, once a spray regime with pyrethroids, or other insecticides that kill adult flies, is introduced, few, if any, flies should be caught on sticky traps. If they are caught, then this should raise an alert. If carrot flies are in the crop at the time it is sprayed with such insecticides, they will be killed. Females have a diurnal pattern of activity, usually leaving the shelter of field boundaries to lay their eggs. To maximise the ‘knockdown’ effect, sprays should be applied between 4–6pm on warm days, as this is when most female flies are in the crop. Insecticide residues are also effective.

In trials at Wellesbourne, on the day after lambda-cyhalothrin was sprayed, residues on the carrot foliage killed 95% of flies. Even after 18 days, the lambda-cyhalothrin residues still killed about 25% of flies. Under a range of weather conditions, residues of lambda-cyhalothrin on carrot foliage killed more than 50% of the flies/day for at least seven days.

The length of time insecticide residues remain effective on carrot foliage depends upon temperature. Residues of lambda-cyhalothrin on carrot foliage killed more than 50% of flies/day for 10 days at the time of the first fly generation (May max/min = 18°C/8°C), but only for 7 days during the warmer months (July/August max/min = 23°C/11°C) of the second fly generation. Sprays of lambda-cyhalothrin became ‘rainfast’ as soon as they contacted the plant foliage. The insecticide was not washed off the plants even when irrigation was applied within 1 minute of applying the spray.

Chlorantraniliprole is also approved for use as a foliar spray treatment to control carrot fly on carrot. In trials undertaken in 2013 and 2015 (FV 414, FV 445), two sprays of chlorantraniliprole were as effective as four sprays of lambda-cyhalothrin and addition of lambda-cyhalothrin sprays to chlorantraniliprole spray programmes led to no additional improvement in carrot fly control. In contrast to pyrethroids, it appears that chlorantraniliprole is most effective against carrot fly larvae.

Thiamethoxam seed treatment provides a certain amount of carrot fly control when carrots are young (FV 445).

### Aphids

Aphids may be controlled using thiamethoxam seed treatment, pirimicarb, spirotetramat or thiacloprid. Recent data collected at the University of Warwick (unpublished) suggests that pyrethroids are less effective against willow-carrot aphid than some other treatments. Some peach-potato aphids are resistant to pyrethroid insecticides and to pirimicarb.

Trials in 2015 (FV 445) showed that thiamethoxam seed treatment reduced aphid infestations more effectively than other treatments. There are also indications that this treatment may reduce virus transmission compared with foliar spray treatments, but this aspect requires further investigation.

### Cutworms

Turnip moth caterpillars are most vulnerable to insecticides while feeding on the foliage (before the third larval instar) and output from the cutworm model can be used to inform treatment timings. Insecticides that are recommended include pyrethrins and several pyrethroids. Biopesticide treatments containing the *Bacillus thuringiensis* toxin (Bt) or entomopathogenic nematodes are available. Turnip moth caterpillars can also be controlled at this time by the application of irrigation.

### Celery fly

Good crop hygiene can reduce the fly population. Infested plant material should be destroyed to kill the larvae and pupae. Spinosad is approved for control of celery fly on celery.

### Mirid bugs

Insecticides approved for use on celery are pymetrozine and pyrethroids including lambda-cyhalothrin, as well as spinosad. Pyrethrins are also approved. Tests in 2016 in which adult mirids were exposed to treated plants (FV 441) indicated that, of these, lambda-cyhalothrin and spinosad were the most effective insecticides.

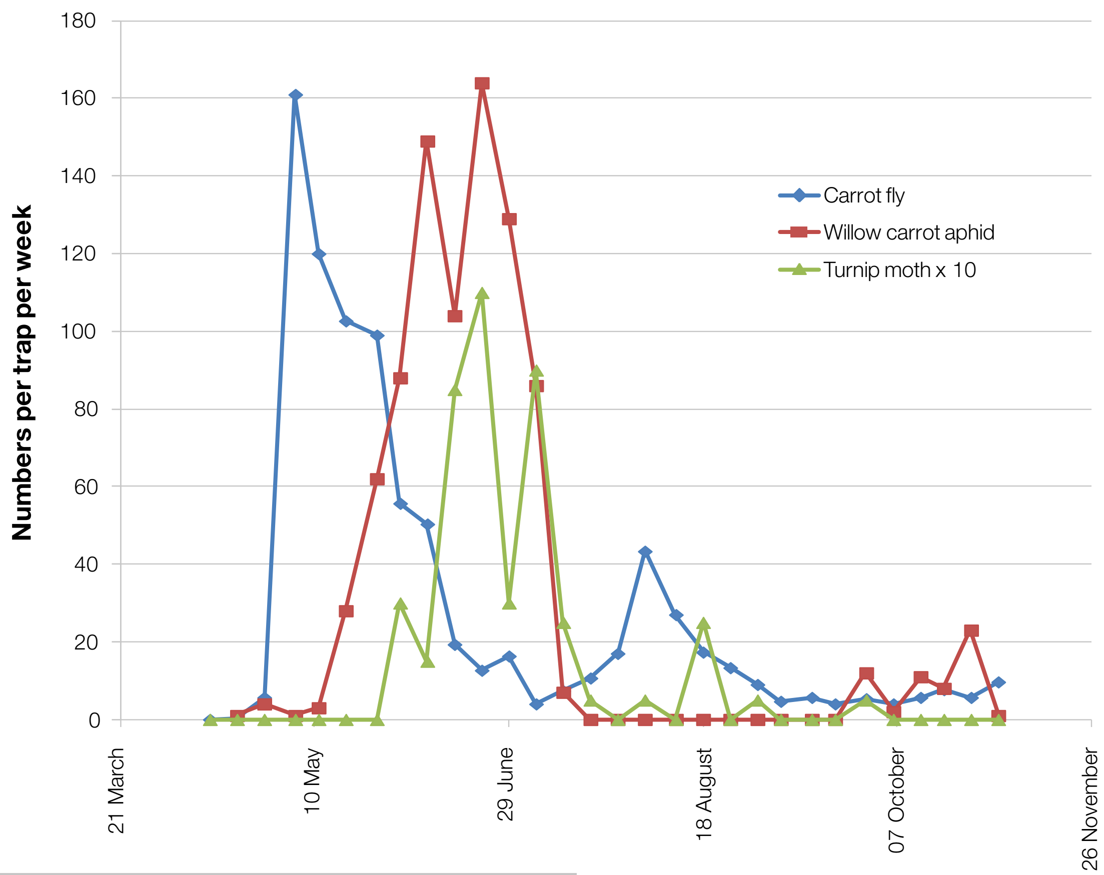


Figure 14. Numbers of insects captured per trap per week at Wellesbourne in 2015. Turnip moth numbers have been multiplied x 10

## Whole crop IPM strategy

Figure 14 shows the numbers of pest insects infesting carrot captured per trap per week at Wellesbourne in 2015. Particularly in May and June, there are periods when two or more pests may be present in the crop.

### Reducing the overall level of infestation

As part of a whole-crop IPM strategy, the cultural methods described above for individual pest species should be deployed, wherever possible, to reduce the overall level of infestation. For both carrot fly and transmission of virus, it is likely that crop rotation and particularly spatial separation of new crops from previous sources of infestation will reduce pest and virus damage. The use of net covers may be beneficial for the control of all pest species, if deployed at the appropriate time and with a suitable mesh size.

### Protection of beneficial insects

All pest species have natural enemies that regulate their numbers to some extent. Studies at Wellesbourne have shown that predators such as ladybirds and parasitoid wasps can be very effective in reducing aphid infestations on carrot in some years. As yet, it is not known what impact this may have on transmission of virus. Where feasible, selective pesticides and/or methods of application should be used to protect beneficial species.

### Insecticides

The insecticides approved on carrot are shown in Table 1. Several of these insecticides are effective against more than one pest species and so careful selection of insecticide treatments based on the life cycles of all potential pests is recommended. For example, thiamethoxam seed treatment will control aphids and carrot fly, although its efficacy will depend on the interval between sowing and the arrival of pests.

### Resistance management

Repeated use of one insecticide group can select for insecticide resistance in the local population. It is therefore good practice to use different modes of action in rotation. Resistance to pyrethroid insecticides and pirimicarb in *Myzus persicae* is well established.