FACTSHEET 14/15

Soft Fruit

Projects SF 80, SF 90 and Defra Horticulture LINK Project HL01107

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Western flower thrips control in strawberry

Western flower thrips (WFT) cause significant financial losses for strawberry growers in the United Kingdom. This factsheet provides information on the pest, the damage it causes to strawberries and the results of AHDB funded research in Projects SF 80, SF 90, SF 120 and a study of control in commercial strawberry production sites, which have led to a series of control guidelines.

1. WFT feeding in strawberry flower

2. Damage to strawberry caused by WFT feeding

Action points

Most successful control of WFT in commercial strawberry production has been found where:

- Strawberry crops are only grown for one season.
- Well-managed regular predator release strategies are used in all crops from either before flowering or from the first flowers, using *Neoseiulus cucumeris*, combined with one or more of: *Stratiolaelaps scimitus*, Orius species (later in the season when temperatures are high enough for establishment) or mass trapping with blue sticky roller traps.
- *Phytoseiulus persimilis* is used as the main control method for two spotted spider mite.
- Crop protection programmes that are harmful to predators are avoided.
- Advice on biological control programmes is sought from an adviser who is experienced in using predators.
- Product compatibility tables are consulted to check if proposed crop protection products are likely to be harmful to the predators being introduced.

Introduction

Western flower thrips – WFT (*Frankliniella occidentalis*) first became a pest of protected ornamental and edible plants in the UK in the 1980s and considerable research has been done since then on management in protected crops. It wasn't until 2002 and later that the pest was found to be damaging protected and outdoor strawberry crops, the first outbreaks being found in the midlands of England. Feeding by the pest was causing serious damage to developing flowers and fruits and this prompted AHDB to commission a series of research projects on WFT control in strawberry, running from 2006 until 2015 and a further study in 2014, comparing poor and successful control on commercial sites. This culminated in a set of management and control guidelines for commercial strawberry growers that are summarised in this factsheet.

Thrips species

There are many different species of thrips native to the UK. Those that can commonly occur in strawberry flowers include the onion thrips (*Thrips tabaci*), the rose thrips (*Thrips fuscipennis*) and *Thrips major* (no common name). Often these occur in species mixtures. WFT is not a native species of the UK, having been first introduced to the UK on infested plant material in 1986. It thrives in warmer temperatures and with the increase in strawberry production under protected structures, the pest is now widespread in all areas of the UK including Scotland.

Fruit bronzing similar to that caused by WFT has been seen where onion thrips or rose thrips are present, with rose thrips (Figure 3) in particular being found in high numbers in strawberry flowers in recent years. Cereal thrips (eg *Limothrips cerealium*) can reach very high numbers in warm thundery weather, at harvest time and when cereal crops/hay/grass verges are cut during the summer months and may occasionally be found in strawberry flowers, but they do not breed on strawberry or cause significant damage.

3. Rose thrips are commonly found in strawberry flowers and should not be confused with WFT

Recognition and biology

Adults

Like other thrips species, WFT adults are small slim insects, with narrow wings fringed with hairs. Female WFT are slightly larger (1.5–2mm long) and darker than the males. The females (Figure 4) usually have a yellowish head and front half of the body and a brownish back half. The males are yellowish all over. Adults can live for several weeks. The temperature threshold for WFT flight is 20°C but they can be active and egg laying in flowers at temperatures below this. Confirmation of species present in the crop needs to be done under a microscope.

4. WFT adult female

Eggs

WFT eggs are not visible as the females lay them directly into plant tissue. Time to egg hatch is about five days at 20°C.

Larvae

Larvae (Figure 5) hatch from the eggs after a few days, depending on temperature. There are two larval stages, neither of which have wings. First stage larvae are less than 1mm long and colourless or white. They feed for two or three days before developing into the second stage larvae, which are about 1mm long and yellow. The second larval stage lasts for about 11 days at 20°C and five days at 25°C, but develops more slowly at lower temperatures.

When fully grown, most of the late second stage larvae drop from the plants to pupate in the soil, growing media or substrate. However, a small proportion may pupate on the plants, in sheltered places such as behind the calyx on fruit or hidden in flowers.

5. WFT larva

Pupae

There are two pupal stages, the prepupa and the pupa (Figure 6), neither of which feed. Both these stages are yellowish in colour and about 2mm long. The prepupa has short immature wings and short, forward-pointing antennae. The prepupal stage lasts only for a day or two then develops into the pupa, which has longer immature wings and longer antennae that fold backwards over the body. The pupal stage lasts for about five days at 20°C and three days at 25°C. When pupation is complete, the adult thrips emerges from the pupal case.

6. WFT pupa

Survival and development

Research in Project SF 80 confirmed that WFT tends to be a greater problem in fields with a history of WFT and where plants or beds are kept from one year to the next. It was found that adults emerged in March from the soil in planting holes directly under the strawberry plants, the soil or substrate close to the plants within the raised beds or grow bags, the straw in the alleys and the soil under the straw. Project SF 120 also found WFT overwintering as adults in senescent or dead strawberry flowers and weeds such as chickweed, groundsel (Figure 7) and dandelion and the first larvae were found in groundsel flowers in late March, indicating that females were laying eggs in early March. WFT are often found on the edges of the crop and especially in weedy field margins. Second year crops can start the season with significantly more WFT that first year crops.

Western flower thrips eggs, larvae and pupae can develop slowly below 10°C, but most information on development rates has been obtained at 10–35°C. WFT can survive in a quiescent state at lower temperatures over the winter. At typical summer glasshouse fluctuating temperatures, WFT can develop from egg to adult in only 11 days. The pest can therefore breed very quickly during the summer and can go through many generations per year, particularly in heated structures (Figure 8) and on everbearers, which have a long season with several flower flushes. Once the pest is established, the highest numbers tend to be concentrated where temperatures are higher, and in the case of field grown crops, in the mid to top areas of sloping fields.

8. Many generations of WFT can occur in heated glasshouse structures

7. WFT can overwinter in certain weed species such as groundsel

Crop damage

Damage is often first seen on the flower petals as characteristic brown markings (Figure 9), but WFT adults and larvae prefer to feed on the flower receptacle, and significant damage may have occurred to an individual flower before the petals become marked. When numbers of WFT are high, damage occurs rapidly and the whole flower may gain a brown unsightly appearance. Feeding continues on the surface of developing fruits, which also develop brown markings around the seeds and under the calyx and have a dull, brown or bronzed appearance when ripe, rendering the fruits unmarketable (Figure 10). Yield loss of 15–20% is typical in strawberry crops where WFT control has broken down. Where high populations develop, on everbearers for example, even more severe crop losses can occur, leading to crop write-offs in some cases.

9. Brown markings on flower petals caused by WFT feeding

10. Strawberry fruits damaged by WFT

Monitoring for thrips in strawberry

A sex aggregation pheromone specific to WFT was developed by scientists at Keele University and is available from Syngenta Bioline. The pheromone is produced by WFT males and attracts both male and female WFT for mating. The pheromone is supplied commercially, adsorbed onto small rubber lures that are stuck onto the lower section of blue sticky traps (available from most Integrated Pest Management – IPM – suppliers) to help monitor for WFT. A different thrips attractant for various thrips species including WFT is available from Koppert. As this attractant is not selective, it will not help to distinguish thrips species. If used on sticky traps it will also attract natural enemies such as Orius, so possibly reducing numbers of predators in the crop.

11. Blue sticky trap used for monitoring before flowering

Before the crop starts flowering, early emerging WFT adults that have overwintered in the crop can be found on flowering weeds. At this time, blue sticky traps together with the pheromone lure are very effective at catching WFT. Each trap can catch several hundred adults per week at times in Spanish tunnels in the UK, depending on the numbers of WFT that have overwintered in the crop. In strawberry, the best position for traps is to mount them onto a post (a cheap bamboo cane is sufficient), held in place with a rubber band with the bottom of the trap (landscape orientation) about 10cm (one hand width) above the top of the crop, orientated to face south so that it catches more light (Figure 11). Once the strawberry flowers start to open, counts of thrips in flowers have been found to give a better correlation with damage than pheromone trap catches. This is because thrips flight onto sticky traps varies with the daily temperature and wind strength, so does not reflect the population density as well as counts of thrips in flowers.

12. Use of a hand lens is essential when monitoring for thrips

The first strawberry flowers in tunnel crops are usually seen in March. They attract adult thrips, and the females immediately start to lay eggs. The thrips concentrate in the yellow stamens and anthers as they feed on the pollen. When monitoring for thrips in strawberry flowers, the selection of flower age and position affects population estimates. For monitoring thrips adults, select flowers of medium age (all petals present, pollen shed) from the top of the plant, as young (petals fresh, pollen not shed) or senescent (petals dropping) flowers will result in an underestimation. For monitoring thrips larvae, select senescent flowers (petals dropping).

Look in the flower centres using a x10 hand lens (Figure 12 – page 5). The yellow parts (carpel) host the thrips, although the adults are commonly found crossing over the petals, into and around the sepals.

Low numbers of adults can be missed as they weave deeply amongst the stamens. There are various ways of exposing the adults:

- Tap the flower sharply onto a hand or preferably a piece of paper on a clipboard or in a notebook and watch adults and larvae run for cover. This is the best way to count numbers of thrips per flower. Tap a minimum of 20 flowers to get a good idea of the mean numbers per flower, as numbers can vary considerably between flowers.
- Gently blowing into the flower centre forces the adults out onto the petal.
- Peel the petals and sepals back and look straight into the side of the carpel.

Understanding how and why damage develops during the season

The first signs of damage will occur in fields where growers have failed to gain control of WFT with spinosad (Tracer) or where an IPM programme has not been well managed. A microscopic examination by an entomologist is the only way to make an accurate identification of thrips species. Early signs of damage are seen as brown rasping under the calyx. Adult thrips should be easily found at this stage. Bronzing damage to strawberry fruit increases with increasing numbers of adult thrips per flower. Green and white berries of all sizes will be bronzed, remaining so until ripe. Damage may only affect parts of a berry, but in severe cases the whole berry can be affected. Berry bronzing can be seen as early as April under tunnels, as green berries develop, but damage levels to everbearer fruit are often highest in July and August, when WFT populations have increased.

Research in Project SF 120 showed that both the adult and larval stages of WFT can cause damage to all stages of flowers and fruit, with the larvae found to cause about twice as much damage as the adults. On everbearers, the worst damage occurs to fruit developing from flowers occurring towards the end of a flower flush, when the thrips adults congregate on the few available flowers, thereby increasing the pest numbers per flower.

Damage thresholds

Research on damage thresholds in everbearers (Project SF 120), demonstrated that in the absence of predatory mites to control WFT, significant damage that might result in downgrading of fruit, occurred when there were about four adult thrips per flower on cv. Camarillo. However, in controlled experiments, when the predatory mite *Neoseiulus cucumeris* was present in flowers, this figure was higher, with significant damage being avoided when there were up to eight adult thrips per flower. No detailed information on damage thresholds is available for other everbearer varieties.

Interestingly, in experiments in commercial crops where predators had been released but their establishment had been poor, economic damage was observed where numbers of adult WFT were at five per flower or above. In contrast, in commercial crops where predators had been released and established well, economic damage was not observed until numbers of adult WFT were as high as 11 adult thrips per flower.

Control

Within the Defra and AHDB funded projects, research has investigated three forms of control including the use of sticky roller traps, biological control using predatory mites and bugs and the use of biopesticides and selective crop protection products.

13. Blue sticky roller traps can in some seasons, help to reduce numbers of WFT

Sticky roller traps

Research was done (Project SF 120) to assess the efficacy of using blue sticky roller traps (30cm wide, 100m long) with and without additional WFT aggregation pheromone along the tunnel legs to reduce adult WFT populations (Figure 13). The traps were tested in addition to releases of predatory mites as part of an IPM programme. In one season, the traps on their own reduced WFT numbers in the crop by 61% and resulting fruit damage by 55%, giving a direct economic benefit to growers of about £2,000 per ha. With the addition of the pheromone, use of traps reduced WFT numbers by 73% and fruit damage by 68%. However, the traps alone (without predatory mites) were not sufficient to prevent fruit damage in crops with high thrips numbers. In 11 trials over three seasons, the traps typically reduced thrips numbers by about 50%, however results were variable. In some trials, WFT numbers were successfully reduced by the traps, but not the level of fruit damage. Where WFT numbers were low, for example, when good biological control programmes were used, the traps did not give a benefit. As research results were variable, growers should not rely upon traps on their own to control WFT, but only as part of an integrated control programme with predators. The traps are most useful at sites with a history of poor WFT control and in higher risk crops (eg second-year crops). They were more effective from July to September when thrips fly more frequently than in April to June when it is cooler.

The traps remain sticky for two months, but after they are first rolled out, there is a lag before they have any effect (as it takes time for thrips numbers to build up in the crop), so it is recommended to put them out about three to four weeks before damage is expected. It should be noted that the aggregation pheromone is a precision monitoring tool and there is no approval for its use as a control agent in commercial crops at this time.

Biological control

In initial studies on biological control of WFT using the predatory mite *Neoseiulus cucumeris* in Project SF 80, it was demonstrated that use of the predator could reduce the numbers of damaged or bronzed fruit when compared to untreated control plots (Figure 14). It should be noted that *N. cucumeris* feeds on the first larval stage of WFT, but not the adults or second stage larvae. Like other predatory mites, it seeks its prey by crawling across the foliage, flowers and fruit. *Orius laevigatus* predatory bugs were also found to offer some level of biological control. A number of commercial growers have had some success with *N. cucumeris*, so further work was done in the Defra Horticulture LINK project (SF 120) to determine the best ways to improve efficacy.

14. *Neoseiulus cucumeris* successfully reduces WFT populations

To provide acceptable control of WFT, it was found that it is best to release *N. cucumeris* early in the season before thrips numbers begin to increase. In commercial practice, this is normally in mid-March in tunnel grown crops. It was shown in the trials that equal control was given whether the predators were released in sachets (Figure 15) or in the loose formulation (Figure 16). However, whichever release system is used, it is necessary to continue to release *N. cucumeris* regularly throughout the season. Commercial success has been achieved in tunnel everbearer crops when the predator has been released using the loose product every two weeks from mid-March onwards, when flowering is beginning, through to mid-September. The normal rate at present for prevention of thrips is 25 per plant per application although this rate is often increased to 50 per plant if numbers of thrips per flower increase. This rate of introduction is based on the experience of ADAS consultants working closely with grower businesses where successful control is now regularly achieved. An AHDB Horticulture training video is available on the AHDB Horticulture website to guide staff on how best to introduce the predatory mite *N. cucumeris* to a strawberry crop.

15. Sachet formulations of *Neoseiulus cucumeris*

16. Loose formulation of *Neoseiulus cucumeris* in a strawberry crop

Further work in Project SF 120 investigated the use of *Orius laevigatus* (Figure 17 – page 8) to supplement the control gained by *N. cucumeris*. Unlike *N. cucumeris*, Orius adults can fly to find WFT and the predator feeds on both adults and larvae, which is advantageous. However, it only works well in the warmer months from late May and June onwards, as it needs a minimum of 15°C for egg-laying to occur and needs over 20°C for good establishment. As a result, populations take time to build up so can't be relied on as a preventive measure. Commonly used rates of introduction for Orius are a minimum of 0.25 to one bug per strawberry plant, which should be repeated two weeks later. Higher release rates have successfully been used in recent years when temperatures have allowed good establishment.

17. *Orius laevigatus*, which can be used to supplement *Neoseiulus cucumeris*

18. *Stratiolaelaps scimitus*

In commercial practice, the use of the soil living predatory mite *Stratiolaelaps scimitus* (formerly *Hypoaspis miles*) to control thrips larvae (when they fall to the ground to pupate) and pupae, has been found to help augment control by other methods (Figure 18). Preventive introductions of 100mites/m^2 are normally used.

The biocontrol costs of using this type of programme are high, but are still significantly less expensive than the financial losses incurred by WFT damage to the crop, which can be >40% of lost tonnage in everbearer crops.

It should be noted that products commonly used for capsid control in commercial strawberry plantations such as the pyrethroid lambda-cyhalothrin (Hallmark) and the organophosphate chlorpyrifos (Equity), are very harmful to, and persistent against, *N. cucumeris* and *O. laevigatus*. Horticulture LINK Project HL 0184 (HDC Project PC/SF 276) led to the commercial development of capsid traps, which contain lures using the female sex pheromone of common green capsid and European tarnished plant bug. These traps are commercially available and enhance the early detection of these pests, which could allow for more timely application of crop protection products. Reducing weeds within the crop will also help to reduce the capsid threat.

Similar harmful products may also need to be used in the control of spotted wing drosophila, *Drosophila suzukii*, (SWD). It is therefore vital that good early season biological control of WFT is achieved before the use of any such products are required. Failure to control WFT early in the season will create a conflict in control options for both pests later in the year when SWD populations start to increase.

Biopesticides

Work in Project SF 120 investigated the use of several biopesticides for controlling WFT. Products tested included foliar applications of Mycotal (*Lecanicillium muscarium*), foliar and drench applications of Naturalis-L (*Beauveria bassiana* – Figure 19), soil drench application of Met52 (*Metarhizium brunneum* – formerly *Metarhizium anisopliae*) and foliar and drench applications of a coded botanical biopesticide. Despite some favourable results using Naturalis-L in laboratory based experiments, in field experiments none of these products were effective. Further work is required to evaluate the persistence of the fungal spores on the strawberry crop and to determine the number of spores per thrips required to cause death.

19. Thrips infected with *Beauveria bassiana*

Traditional crop protection products

Soon after the first appearance of WFT in UK grown strawberry crops, the AHDB secured an Extension of Authorisation for Minor Use (EAMU) for the use of Tracer (spinosad) on strawberry crops to control WFT. However, experience of using spinosad overseas had indicated that populations of WFT can develop resistance to this product quite rapidly. In anticipation of resistance developing in the UK, AHDB funded Project SF 90 to assess alternative control products.

A number of approved and non-approved products were included but none of these consistently reduced numbers of WFT during flower development throughout the trial. Interestingly, the population of WFT used in the second year of this trial was shown to be resistant to Tracer.

In the early stages of Project SF 120, some other coded products were assessed for their potential at controlling WFT and compared with Tracer. In Year 2 of the project, two coded products compared favourably with Tracer, providing 80 and 81% control respectively, compared to 69% control achieved by Tracer. These coded products are not currently approved for use on strawberries in the UK. AHDB Horticulture is investigating the potential for securing future approvals on strawberry.

However, in the short to medium term, growers will need to rely primarily on the use of biocontrol techniques for controlling WFT.

Reasons for success and failure occurring in commercial practice

20. Particularly heavy losses to western flower thrips occurred in 2013 and 2014

In 2013 and 2014, a significant number of UK strawberry growers suffered particularly heavy losses of yield as a result of failing to achieve acceptable control of WFT (Figure 20). In light of the knowledge gathered both from AHDB funded research projects and related experience gained working with commercial strawberry producers, AHDB Horticulture funded a study of selected strawberry production sites. The aim of this study was to identify factors that may have led to the success or failure of WFT control in tunnel grown strawberry, which could be disseminated to growers to improve their control.

Six growers were visited or interviewed (two in Kent, three in Staffordshire and one in East Anglia) and details were collected from six crops where WFT control was successful and six crops where it had broken down. Growers provided more general details about their site history, growing details, pest and disease control methods, monitoring methods and decision-making processes. Treatments were reported up to the end of July 2014, which reflected the time of the survey and included the early season, which is the key time for establishing natural enemies that are essential for WFT control.

Summary of the crucial findings

WFT control was most successful where:

- Only one-year strawberry crops were grown.
- Well-maintained regular predator release strategies (Figure 21 – page 10) were employed (in first – or second-year crops) either from or before flowering, using *Neoseiulus cucumeris* combined with:
  – *Stratiolaelaps scimitus* (formerly named *Hypoaspis miles*) and Orius spp.
  or
  – *Stratiolaelaps scimitus* and mass trapping with blue sticky roller traps.
  or
  – *Stratiolaelaps scimitus*, Orius spp. and mass trapping with blue sticky roller traps.
  or
  – Mass trapping with blue sticky roller traps.
- *Phytoseiulus persimilis* was used as the main control method for spider mites.
- Pesticide programmes that are harmful to predators were avoided.

21. Success is achieved using regular predator releases either from or before flowering

WFT control broke down where:

- There was a large carry-over of WFT from the previous season, either from overwintered first-year crops or from reused, untreated growbags, resulting in damage at first flowering.
- Predators were released too late.
- Insufficient *N. cucumeris* releases were made early in the season.
- Crop protection products (Figure 22) that are harmful to predators were used during the time when predatory mites were being released, or there was repeated use of slightly/moderately harmful products, which prevented predator establishment and interrupted WFT control.

22. Control breaks down when products that are harmful to predators are applied during the predator establishment phase

Specific control guidance for growers

At the end of the study to identify the differences between the successes and failures, practical guidance was produced for growers to follow to achieve successful control of WFT. This guidance is reproduced in the insert in the back cover of this publication.

Further information

Other useful publications

AHDB Grower guide. Biocontrol in soft fruit.

AHDB Factsheet 14/09. Thrips control on protected ornamental crops.

AHDB Study report. Management of pesticide-resistant western flower thrips on tunnel-grown strawberry: a study of the reasons for successes and failures on commercial production sites.

AHDB Biocontrol training video. Using *Neoseiulus cucumeris* for western flower thrips and tarsonemid mite control (translated into Bulgarian, Romanian, Latvian, Lithuanian, Polish, Slovakian).

Useful AHDB project reports

SF 80 – Tunnel-grown everbearer strawberry: biology and integrated control of western flower thrips (Project leaders: Jude Bennison, ADAS and Jean Fitzgerald, East Malling Research).

SF 90 – Chemical control of western flower thrips in strawberry flowers (Project leader: Jerry Cross, East Malling Research).

SF 120 – Biological, semiochemical and selective chemical management methods for insecticide resistant western flower thrips on protected strawberry (Defra Horticulture LINK HL01107).

PC/SF 276 (HL0184) – Pheromone technology for management of capsid pests to reduce pesticide use in horticultural crops (Project leader: Michelle Fountain, East Malling Research).

Defra Horticulture LINK project (HL01107 – SF 120) consortium details

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Industry leader: Richard Harnden, Berry Gardens Growers

Consortium members:
East Malling Research
Natural Resources Institute
ADAS
Keele University
Warwick Horticulture Research International (HRI)
AHDB Horticulture
Bayer CropScience
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