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

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Disclaimer

Contents

Background and purpose of this study

The western flower thrips (WFT) is a non-indigenous pest in the UK that has extended its range into tunnel-grown strawberry crops over the last decade. Pesticide-resistant strains are widespread, which cannot be controlled with the chemical insecticides currently approved for use on strawberry (HDC Project SF 90). Yield loss of 15-20% is typical in strawberry crops where WFT control has broken down.

Control relies on integrating the use of predators (*Neoseiulus cucumeris*, *Stratiolaelaps scimitus* and *Orius* species) with cultural and physical methods and carefully timed treatments of compatible pesticides (HDC project reports SF80, SF90, SF120). At present, some growers incur heavy losses due to WFT, yet other growers are routinely successful in achieving control.

The aim of this study was to identify some factors that have led to the success or failure of WFT control in tunnel-grown strawberry, which can be disseminated to growers in order to improve their control.

The study was led by Clare Sampson of Keele University, who consulted with William Kirk (Keele University) and Robert Irving (ADAS).

Summary of the crucial findings

Western flower thrips (WFT) control was most successful where:

- Only one-year strawberry crops were grown.
- Well maintained regular predator release strategies were employed (in first- or second-year crops) either from or before flowering, using *Neoseiulus cucumeris* (=*Amblyseius cucumeris*) combined with:
    - *Stratiolaelaps scimitus* (= *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.

Western flower thrips (WFT) control broke down where:

- There was a large carry-over of thrips from the previous season, either from over-wintered first-year crops or from re-used, 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 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 thrips control.

Summary of the project

Methods

Six growers were visited or interviewed (two in Kent, three in Staffordshire and one in East Anglia) and details were collected about six crops where thrips control was successful (Fields 1-6, Tables 1-3, Appendix 1) and six crops where it had broken down (Fields 7-12, Tables 1-3, Appendix 1). Growers provided more general details about their site history, growing details, pest and disease control methods, monitoring methods and decision-making processes. Treatments are reported up to the end of July 2014, which reflects the time of the survey and includes the early season, which is the key time for establishing natural enemies which are essential for thrips control.

Factors affecting thrips control

Growing methods and cultivars

Most thrips control failures were found to occur in second-year everbearer crops. Thrips were adequately controlled on 60-day crops and on most first-year everbearer crops where good IPM (Integrated Pest Management) programmes were used. Control failure was found in both soil-grown and substrate-grown crops. All everbearer cultivars included were susceptible to WFT damage, including Camarillo, Albion, Finesse, Amesti, Jubilee, Diamond, Serena, Eves Delight and Red Glory.

Two farms (one in Staffordshire and one in Kent), which had previously lost more than £100,000 per annum to WFT, achieved good thrips control in all everbearer crops grown in 2013 and 2014 (to the end of July - a total of 12 crops) by only growing one-year old crops and using well-maintained IPM programmes.

Several growers are moving away from soil-grown crop production and are testing different mulches and floor coverings, but none of them knew how the mulches affected thrips development or damage to strawberry. Some mulch colours are known to affect thrips populations and fruit bronzing symptoms. In studies by Brown *et al* (1989), more thrips were found on tomato plants above white plastic mulches than above black and aluminium mulches. Some growers use blue mulches and this colour is known to attract thrips.

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All growers included in this study were aware that thrips breed on a wide range of weed species. Each achieved routine weed control with varying success. Fruit damage tended to be worst around the field margins in first-year crops (near weeds) and beside weedy areas between tunnels. Two growers reported fruit damage in June and around harvest time from darker coloured thrips that were not WFT. These species were likely to be a mix of *Thrips major, Thrips fuscipennis* and cereal thrips and, unlike WFT, they were well controlled by spinosad (Tracer).

Predator release strategies for thrips control

In all the crops where thrips control was successful, the predatory mite *N. cucumeris*, which feeds only on thrips larvae, was released regularly from the start of, or from before first-flowering (e.g. from the end of March/beginning of April) (Table 1, Appendix 1). Breeder packs (sachets) were typically used for the first releases, applied at about one sachet per two linear metres of crop. Sachets offer some protection from weather and pesticides and provide food for the predators when pollen is scarce, which improves early-season establishment (see HDC Project SF 94/ Defra Hort LINK Project HL0191, 2013 report).

Establishment can be achieved by introducing sachets every 4-6 weeks or by more frequent releases of loose predatory mites, according to grower preference. For loose *N. cucumeris,* recommended release rates of a minimum of 25 *N. cucumeris* per plant, applied fortnightly from first flower, were generally effective when harmful crop protection product treatments were avoided. Higher *N. cucumeris* release rates may be required in second-year crops where large numbers of thrips have overwintered (e.g. Field 5, Table 1, Appendix 1). Good *N. cucumeris* establishment can result from fewer releases when pesticide use is minimised (e.g. Fields 1, 4, Table 1, Appendix 1). However, repeated *N. cucumeris* releases (e.g. Fields 2, 3, 5, 6, Table 1, Appendix 1) are cost-effective and offer growers more reliable protection. These are needed to maintain predator establishment when repeated applications of slightly harmful pesticide treatments are used to control other pests and diseases (Tables 2 and 3, Appendix 1).

The study revealed that *Neoseiulus cucumeris* had also been released in fields where thrips control broke down. Thrips control failure in these fields was likely to be due to poor establishment of predatory mites, either because of untimely releases of the predators (Fields 7-9, Table 1, Appendix 1), use of incompatible pesticides (Fields 7-12, Tables 2 and 3, Appendix 1) or a combination of both.

The soil-dwelling predatory mite *Stratiolaelaps scimitus*, which feeds on thrips pupae in the soil, can be a useful back-up to *N. cucumeris* and was released in five of the six crops where thrips control was successful, and in only one of the six crops where thrips control broke down. In controlled scientific trials on strawberry by Rahman *et al* (2011), it was found that although *S. scimitus* is insufficient to control thrips on its own, the combined use of *N. cucumeris* and *S. scimitus* resulted in better control than *N. cucumeris* alone. In this new HDC study, it was found that most growers made one release of *S. scimitus* between March and May (Table 1, Appendix 1). The mites should be in place as soon as thrips are breeding in the crop for best effect (the first larvae are usually found two to three weeks after first flowering). In glasshouse strawberry crops, *S. scimitus* is also released in autumn to reduce numbers of overwintering thrips but the effect of *S. scimitus* on overwintering populations outside is unknown.

The predatory bug *Orius* can be extremely effective when used in addition to *N. cucumeris*. Whereas the predatory mites are essential for delaying or preventing early-season thrips population build up (from April to

July), *Orius* bugs take longer to establish and are most effective in the summer months (July to September). When questioning growers in the survey about the advice they receive from crop agronomists on the best timing or rates of release for *Orius,* there appeared to be no consistent message being offered.

Orius established in two of the three crops where it was released (total releases of 1 and 9 per m^2 from weeks 23 and 19 respectively), but failed to establish in one crop (total release of 7 per m^2 from week 16, Field 10). In this case, it was not possible to determine whether this failure to establish was due to the timing of releases or crop protection products used. *Orius* needs warm temperatures and pollen to establish and can be adversely affected by certain crop protection products (Appendix 2). It does not breed below 15°C and thrives in temperatures between 24-30°C. Once established, it is a voracious predator, feeding on adult and larval thrips as well as other small invertebrates. It is capable of bringing summer adult thrips populations under control, resulting in lower thrips populations the following season. Growers cite the relatively high cost of *Orius* as the reason for not releasing it, although experience of poor establishment has resulted in a lack of confidence in its use. Clearer guidelines from advisors on the timing and rates of *Orius* release would be useful for growers.

Two-spotted spider mite control

Where thrips control was successful, the main control method used for two-spotted spider mite was the predatory mite *Phytoseiulus persimilis*, which is the most effective spider mite control available to growers. Most chemical acaricides available for use against two-spotted spider mite during cropping are harmful to predatory mites. Products such as etoxazole (Borneo), abamectin (Dynamec) and tebufenpyrad (Masai) can disrupt the establishment of predatory mites when used during cropping (e.g. Field 7, Table 2, Appendix 1). In two crops where thrips control was successful, abamectin (Dynamec) or tebufenpyrad (Masai) was applied in March, before *N. cucumeris* was released (Fields 5, 6, Table 1, Appendix 1).

Integration of crop protection products with natural enemies

Where thrips control was successful, growers used fewer insecticide products that were harmful to predators and fewer spray treatments in total than on crops where thrips control had broken down (Table 2, Appendix 1). In the study, where successful biocontrol of WFT had been achieved, it was also found that:

- No long-residual, harmful products had been used (kill >75% *N. cucumeris* for >4 weeks), such as chlorpyrifos (Equity), deltamethrin (Decis) and lambda-cyhalothrin (Hallmark).
- Fewer (about one fifth in total) shorter-residual harmful products were used, such as spinosad (Tracer), abamectin (Dynamec), tebufenpyrad (Masai) and pyrethrum (Pyrethrum 5 EC).
- Moderately harmful products such as pirimicarb (Aphox) and thiacloprid (Calypso) (kill 50-75% *N. cucumeris*) and relatively safe products (kill<25% *N. cucumeris*), such as pymetrozine (Chess), clofentezine (Apollo 50 SC) and bifenazate (Floramite 250 SC), were successfully integrated with natural enemies by limiting their use and timing treatments carefully.

In contrast, where biocontrol measures were unsuccessful, about twice as many insecticide products were applied.

The repeated use of slightly harmful fungicide products (25-50% mortality of *N. cucumeris*) and some tank mixes of insecticide products during key times of predatory mite establishment (April to July), may have contributed to poor predator establishment and thrips control breakdown (Table 3, Appendix 1).

In the study, it was also found that more than twice as many slightly harmful fungicide products were used in fields with poor thrips control than in fields with good thrips control (Table 3, Appendix 1). Other control aspects should be considered:

- When several slightly harmful products are tank mixed, they become harmful to predators. For example, Lash *et al* (2007) found that in controlled trials, spinosad (Tracer) resulted in 44% mortality of *N. cucumeris* nymphs, fenhexamid (Teldor) resulted in 28% mortality, but the mixture of both resulted in 60% mortality. Repeated use of such mixes can affect predator establishment and result in thrips control failure (e.g. Field 11, Tables 2 and 3, Appendix 1).
- The compatibility of some of the newer adjuvants and wetters with predators is unknown and should be checked with suppliers or tested on a small area of crop before using widely (e.g. Wetcit). Most physically active products (e.g. Majestik, SB Plant Invigorator and Codacide oil) that kill small pests, will also kill predatory mites, so repeated use should be avoided.

Mass trapping

Two growers who have adopted routine mass trapping in all crops, report that the traps have reduced fruit damage and improved thrips control on their farms. Both growers started trapping in April and replaced traps in early/mid-July when the traps became less sticky. Trapping can integrate well with the use of predatory mites, as the traps catch adult thrips whilst the predatory mites only feed on larvae.

In replicated experiments by Sampson and Kirk (2013) it was shown that the traps reduce thrips numbers and fruit damage by at least 50% when temperatures are suitable for thrips flight (July to September). Mass trapping is not sufficient to control thrips alone. In this study, control broke down in two of the fields where traps were used alongside biocontrol (Fields 11 and 12, Table 1, Appendix 1). Traps should only be used in addition to predators as part of an integrated control programme.

Monitoring and decision making

- The growers included in this study relied on advisers to monitor both thrips numbers and predator establishment.
- In 2014, none of the growers in the study had recorded the numbers of thrips or *Orius* per flower or predatory mite establishment by field through the season. Although such data is time-consuming to

collect, it is valuable for decision-making and as a learning tool.

- All growers surveyed used two or three different advisers who regularly visit their farms through the season.
- Two of the six growers had received conflicting advice that would prevent predator establishment (e.g. long-residual insecticide products had been recommended during the growing season), suggesting that some advisers also lack experience in using natural enemies.
- None of the six growers received routine visits from the biocontrol supply companies, who have the most experience in how to integrate biological and chemical control methods.
- All growers quoted a damage threshold of between 4 and 10 adult thrips per flower, based on experience or reports. One grower with good predator establishment estimated fruit damage when there were about 10 thrips per flower (cv. Camarillo). One grower with poor predator establishment saw fruit damage when there were less than 4 thrips per flower (cv. Jubilee). This demonstrates that good predator establishment helps to reduce thrips damage and that low levels of WFT can be tolerated, without experiencing economical crop damage, when predators are well established.

Experience in using predators for thrips control

- All the growers visited during the study had lengthy experience of strawberry production and of managing large-scale, commercial farms, but WFT was a relatively new pest, being first recorded within the previous 3 to 7 years.
- The worst control was observed on farms where WFT had arrived most recently.
- Most growers, who first experienced heavy losses five years ago, have improved their control of thrips over the last two seasons, as they have gained experience and confidence in using natural enemies.

Specific comments relating to the fields surveyed

Further details on the compatibility of crop protection products with natural enemies may be found in Appendix 2. Further details on the timing of the product applications used may be found in Appendix 3.

Fields where thrips control was successful (cropping year in brackets):

Field 1 (2013): A first-year crop planted in re-used growbags in a field with a history of WFT crop loss. There was excellent establishment of *N. cucumeris* following careful selection of compatible crop protection products from April to June. Pymetrozine (Chess) was used for capsid control, pirimicarb (Aphox) was used for aphid control and *Phytoseiulus persimilis* was used for two-spotted spider mite control. Some capsid damage was observed and thiacloprid (Calypso) was applied in late August. *Orius* established, although only in low numbers following late release, a low release rate and cool weather. Thrips remained below damaging levels throughout the season.

Field 2 (2014): A first-year crop in re-used growbags. *Neoseiulus cucumeris* was released fortnightly from flowering. Mass trapping with blue sticky traps was used from 6 June and harmful crop protection products were avoided. There was excellent establishment of *N. cucumeris.* A single spinosad (Tracer) treatment was applied in late June when there was an increase in adult thrips in flowers following mowing. No thrips damage was recorded.

Field 3 (2014): A first-year crop in re-used growbags. A number of insecticide treatments were used that could have interrupted predator establishment, including abamectin (Dynamec) in early-May, thiacloprid (Calypso) and spinosad (Tracer) in mid-June. Despite this, no thrips damage was observed, possibly because there was less thrips pressure in this first-year crop.

Field 4 (2013): A second-year crop where thrips were reasonably well controlled by releases of *N. cucumeris* and *S. scimitus*. This field had the lowest number of crop protection product treatments of those surveyed, with only two insecticide product treatments (both of thiacloprid, Calypso, in mid-June and early-July) and 11 fungicide product treatments up to the end of July (Tables 2 and 3, Appendix 1).

Field 5 (2014): Thrips were present in significant (high) numbers from first flowering. Clofentezine (Apollo 50 EC), pirimicarb (Aphox) and abamectin (Dynamec) were applied before predators were released (Table 2, Appendix 1). *Neoseiulus cucumeris* was released in high numbers from flowering, using breeder packs (sachets) for the first three releases to improve establishment. *Orius* was released from early-May to early-June and establishment was excellent following high release rates and mild weather. By mid-July, *Orius* was found in nearly all the flowers and thrips numbers had reduced to below 1 per flower. Good thrips control followed for the rest of the season.

Field 6 (2014): A second-year crop on a farm with WFT. Pymetrozine (Calypso) and tebufenpyrad (Masai), which are both moderately harmful/ harmful to predatory mites for up to two weeks, were applied for capsid and two-spotted spider mite control respectively, before *N. cucumeris* and *P. persimilis* were released. Mass trapping was used. There was some damage from *Thrips major* in July but WFT was well controlled.

Fields where thrips control broke down (cropping year in brackets):

Field 7 (2012): A first-year crop grown in re-used growbags where WFT control probably broke down due to incompatible crop protection product use. WFT and two-spotted spider mites were present from the start. Reasonable numbers of predators were released but thrips control broke down when etoxazole (Borneo, harmful to *P. persimilis* for 4-8 weeks) was used against two-spotted spider mite in late-June, which reduced numbers of *N. cucumeris*. *Phytoseiulus persimilis* was well established at the time of the etoxazole (Borneo) treatment, so the application may have been unnecessary.

Field 8 (2014): Thrips control broke down in this second-year crop due to incompatible crop protection product use and late release of predators. Lambda-cyhalothrin (Hallmark) was used in mid-April, which has a 6-8 week harmful residual effect on predators. *Neoseiulus cucumeris* was not released until early-July, by which time thrips adult numbers had already built up.

Field 9 (2014): Thrips control broke down in this second-year crop because *N. cucumeris* was not released until July, by which time thrips numbers had already built up to high numbers. Repeated spinosad (Tracer) applications failed to bring the thrips under control.

Field 10 (2014): In this second-year crop it is less obvious why thrips control broke down. Predator releases were high, although there was a five-week gap in releases of *N. cucumeris* during May at the critical time for establishment. Powdery mildew levels were high and the repeated applications of tank mixes of slightly harmful fungicide products (nine applications up to the end of June) may have interrupted predator establishment. Advisers reported no establishment of *Orius* and *N. cucumeris*. Although some harmful insecticide products were used (Table 2, Appendix 1), these were applied in July, after control had broken down (Appendix 3).

Field 11 (2014): Although there was a good predator release programme in this field (Table 1, Appendix 1), establishment of the predatory mites was poor. This was most likely due to a chlorpyrifos (Equity) treatment in late March and repeated sprays (x4) of harmful tank mixes of spinosad (Tracer), fenhexamid (Teldor) and sulphur in May/June at a critical time for predator establishment.

Field 12 (2013): There was a high carry-over of thrips from the previous season and thrips control was a concern from early June. The grower applied repeated applications of short-residual, moderately harmful products from mid-June to mid-July in order to try and bring thrips numbers down (3 x maltodextrin - Majestik, 2 x spinosad - Tracer, 2 x vegetable oil - Codacide oil, 1 x thiacloprid – Calypso). These did not control the thrips and they are likely to have had a negative impact on predator establishment.

Suggested guidance for 2015

The survey has shown that some farms have repeated success in controlling WFT on semi-protected strawberry using IPM. Adoption of IPM is not easy as it requires changing the control methods used for all pests and diseases. Advice on control programmes should be sought from advisers who are experienced in using predators, before the start of each season.

IPM programmes will vary with the weather, farm location, field history, cultivars, planting dates and with the specific pests and diseases present at the time. The following is an illustration of an IPM programme that can be adapted according to local conditions and advice.

At the end of the 2014 season

- Consider growing one-year crops in fields where thrips control has broken down. Once confidence is gained in using predators, then second year crops can be re-considered.
- Introduce a well maintained biocontrol and/or physical control programme at the end of the season if re-planting new crops in growbags or beds.
- End the season with good weed control which should continue throughout the year.
- If everbearer crops are over-wintered, the control strategy starts in the previous autumn:
  - ➢ Continue to control thrips with predators right up to the end of flowering (flowering and thrips breeding can continue well past the time when the cladding is removed).
  - ➢ Reduce the overwintering thrips population by controlling flowering weeds throughout summer and autumn (especially after cropping).
  - ➢ Use high volume drenching clean-up sprays in late autumn (after cropping) to reduce overwintering aphids and capsid (SF 94/ HL0191).
  - ➢ Avoid the use of long-residual treatments that are harmful to predatory mites in the spring and during cropping, as they kill predatory mites for 6-8 weeks. Such products include chlorpyrifos (Equity) and lambda-cyhalothrin (Hallmark).
  - ➢ Where predatory mites are still present in October to December, consider shorter residual products for aphid and capsid control. Examples include pymetrozine (Chess) or thiacloprid (Calypso).

When the cladding goes on

- Add blue sticky roller traps to the polytunnel 'legs' as soon as the cladding goes on, as the warmer temperatures will increase thrips flight. Place these at flowering height to catch most thrips.
- Apply breeder bags (sachets) of *N. cucumeris* at one per 2 m linear crop.

From first flowering

- *N. cucumeris* is the backbone of thrips control and its use is essential to delay the build-up of thrips populations and to reduce fruit damage. Your spray programme should be adjusted to minimise the impact on the predatory mites.
    - *N. cucumeris* only feed on larvae, so are best used preventively.
    - Establish the mites immediately from first-flowering even if the weather looks unsuitable.
    - Repeat releases of loose *N. cucumeris* fortnightly or weekly at a minimum of 25 per plant from first flowering and repeat releases throughout the season, until they are present on the majority of fruit, or until *Orius* is well established.
    - An alternative strategy is to use *N. cucumeris* breeding sachets monthly.
- Biological control with predatory mites relies on continual good distribution of live mites throughout the crop. Take care to ensure that the predators are well mixed, well distributed and not left out in the sun (cooked) before application.
- Apply *S. scimitus* (*Hypoaspis miles*) once at about 10 per plant.
- Start monitoring weekly. It can be helpful to count and record the numbers of adult thrips per flower from 10 flowers from an area of the field where thrips are worst. When fruit are present, look under the calyx of 10 fruit per area and record the presence or absence of predatory mites. However, be prepared to maintain repeat releases of *N. cucumeris* as the season progresses as this has proved to be successful.
- Time releases of *Orius* (in addition to *N. cucumeris*) according to temperature, flower availability and your crop protection product treatments. Make at least two releases when temperatures are suitable (e.g. in May) and only in fields where harmful products have been avoided. *Orius* should reduce numbers of adult and larval thrips as well as other pest species during late-July and August.
- Avoid routine spraying of spinosad against thrips as this increases resistance and interrupts predator establishment. Crop damage varies between cultivars and regions, but occurred at about 4 adult thrips per flower in Camarillo in Staffordshire when there were few *N. cucumeris*. When predatory mites are well established, higher numbers of thrips adults can be tolerated without fruit damage (up to 10 adult thrips per flower in some crops). *Neoseiulus cucumeris* feed on thrips larvae, which are the most damaging thrips stage.
- Do not use spinosad where existing WFT populations are known to be resistant to it. It is only of use if other thrips species are present and need to be controlled.
- Insecticide treatments may be more effective if applied when thrips flight activity is highest in the middle of the day (as demonstrated by Shipp and Zhang, 1999).
- If spinosad (Tracer) does not work, stop spraying and increase the number of predators released (unless a long-residual harmful pesticide has been used).
- *Beauveria bassiana* (Naturalis) treatments may help but it is unproven in strawberry.

At the end of the main flower flush

- Take account of rapidly changing flower numbers in everbearer crops. There is a period of risk of thrips damage when flower numbers decline and thrips concentrate into fewer flowers.
  - Monitor carefully at this time.
  - Maintain the biological control releases during this period. Breeder packs (sachets) of *N. cucumeris* can be more effective than loose predators when there is less pollen (i.e. when flower density is low).
  - Replace the roller traps in July once the first batch become less sticky. Trapping is most effective during the summer months.

Control of other pests and diseases

- Use IPM-compatible products for the control of other pests and diseases. Plan your control programme carefully and always refer to the compatibility data (Appendix 2). For example:
  - Two-spotted spider mite: Use *Phytoseiulus persimilis* as the main control. Apply carefully chosen acaricides such as clofentezine (Apollo) and bifenazate (Floramite 240 SC) to reduce overwintered spider mite if required. If using abamectin (Dynamec) or tebufenpyrad (Masai), treat at least two weeks before predator release.
  - Capsids: Use pymetrozine (Chess) or thiacloprid (Calypso) sparingly as guided by crop inspection and pheromone traps. It may be possible to target the first generation of capsids with thiacloprid (Calypso) in March before predators are released.
  - Aphids: Use an autumn clean-up spray and consider parasitoids in the spring. If further treatment is required in the spring, use pirimicarb (Aphox) or pymetrozine (Chess).
  - Disease control: Work out a fungicide programme with your adviser that minimises the number of sprays (use the latest forecasting systems) and avoids repeated use of the products that are harmful to predators at key times of *N. cucumeris* establishment (see Appendix 2).

At the end of the season

- Continue your biological control programme to the end of the season if you are overwintering crops.
- If you have had good control in year 1, then good control is likely to follow in year 2.
- If thrips are carried over to year 2, you may need higher release rates of *N. cucumeris* the following spring, as there are more thrips in second-year crops (because there will be a higher starting number of thrips and more flowers for them to breed up in). Consult your adviser for release rates.
- If you have ended with high thrips numbers at the end of year 1, it will be much worse in year 2, so consider pulling the crop out.

References

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Shipp JL, Zhang, Y (1999) Using greenhouse microclimate to improve the efficacy of insecticide application for *Frankliniella occidentalis* (Thysanoptera: Thripidae). Journal of Economic Entomology. 92(1): 201-206.

HDC projects and publications referred to

SF 80: Tunnel-grown everbearer strawberry: biology and integrated control of western flower thrips.

SF 90: Chemical control of western flower thrips (WFT) in strawberry flowers.

SF 94: Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management.

SF120: Biological, semiochemical and selective chemical management methods for insecticide resistant western flower thrips on protected strawberry.

HDC Grower Guide: Biocontrol in soft fruit (Bennison J, Irving R, Umpelby, R)

Appendices

Appendix 1 - Crop protection methods used in plantations include in the study

Table 1: Thrips control predators (up to the end of July) and mass trapping used

Field (year of cropping)	*N. cucumeris* week nos. released (sachets in bold)	*N. cucumeris* total loose per plant	*S. scimitus** week nos. released	*S. scimitus* per plant	*Orius* sp. week nos. released	*Orius* sp. total released per m^2 of crop	Mass trapping used?
Fields where WFT was well controlled							
1 (1)	15, 23	163	17	6	23, 25	1	Yes
2 (1)	15, 17, 19, 21, 23, 25, 27	200	13	10			Yes
3 (1)	15, 17, 19, 21, 23, 25, 27	200	13	10			Yes
4 (2)	15, 19, 21, 23	200	20	20			No
5 (2)	14, 15, 16, 24, 25, 27, 28	350	22	10	19, 21, 23	9	No
6 (2)	16, 18, 20, 22, 24, 25, 26, 28, 30	175					Yes
Fields where WFT control broke down							
7 (1)	13, 23, 25, 26, 28, 29	250					No
8 (2)	27	200					No
9 (2)	27	200					No
10 (2)	14, 17, 22, 24	250			16, 18, 19, 21, 22, 23	7	No
11 (2)	15, 17, 19, 21, 23, 25, 27	200					Yes
12 (2)	15, 19, 21, 23	200	20	20			Yes

- *S. scimitus* was formally known as *Hypoaspis miles*.
- Fields 2 and 3 were on the same farm
- Fields 8 and 9 were on the same farm

Table 2: Insecticide treatments used (up to the end of July)

Field	Chess	Natur-alis	Apollo	Flora-mite	Aphox	Calypso	Majestik	Pyreth-rum 5EC	Masai	Tracer	Dyna-mec	Equity	Hall-mark	Decis	Borneo[1]
Fields where WFT has been well controlled															
1	2	1			2										
2						1				1					
3	2		1		3	1				2	1				
4						2									
5			1		1						1				
6					1	2			1						
Fields where WFT control has broken down															
7	1	1			1	1		2		1	1				1
8		2			1	2			1	3			1		
9		2	1	1		1			1	4					
10					1	1				1	1			1	
11			1	1					1	4		1			
12		1	1	1		1	3	1		2		1			

Key:

"Safe" kills <25%	Moderately harmful Kills 50-75%	Harmful when wet Kills>75%	Harmful for 1-2 weeks Kills>75%	Harmful for >6 weeks Kills>75%

[1]The compatibility of Borneo with *N. cucumeris* is unknown but may be harmful for 4-8 weeks in line with other predatory mite species.

Table 3: Fungicides, garlic and adjuvants used (up to the end of July)

Field	Fungicides						Wetters and other products				
	Sulphur	Teldor	Switch	Nimrod	Other 'safe' fungicides	Total no. of fungicides	Silicon e.g SW7 slither	Codacide oil	Attracker (sugars)	Garlic	Wetcit
Fields where WFT has been well controlled											
1		2		1	15	18					
2		1	1	2	16	20	2	1			
3		1	1	2	10	16	3	1			
4		1			10	11					
5	1		1	1	9	12					
6	1	1		4	5	11	3	1			
Fields where WFT control has broken down											
7	4	4	1	2	20	31	2	2			
8	2	1	2	2	12	19	2			5	
9	1	1	1	1	10	14	3			4	
10		3	2	2	12	19					3
11	3	3	1		14	20					
12					6	6	1	2	4		

Key: Slightly harmful, Kills 25-50%

Note: most pesticides were applied as tank mixes. 'Safe' fungicides include: Scala, Parrat, Fortress, Rovral, Amistar, Systhane 20 EW, Serenade, Topas, Frupica, Kindred, Thianosan, Potassium Bicarbonate, Stroby.

Appendix 2 - Side-effects of pesticides used on selected natural enemies

Active ingredient	Typical product	*Phytoseiulus persimilis*	*Neoseiulus cucumeris*	*Orius laevigatus*	Target pest/ disease
Potassium bicarbonate	AgriKarb	No information	Safe	No information	Mildew
abamectin	Dynamec	Harmful (1-2 weeks)	Harmful (2 weeks)	Harmful (3-6 wks)	Spider mite
azoxystrobin	Amistar	Safe	Safe	Safe	mildew
Bacillus thuringiensis	Dipel DF	Safe	Safe	Safe	caterpillars
Beauveria bassiana	Naturalis-L	Safe	Safe	Safe	Various
bifenazate	Floramite 240SC	Moderately harmful (1 week)	Safe	Safe	spider mite
bupirimate	Nimrod	Slightly harmful (4 days)	safe	Slightly harmful (? days)	mildew
chlorpyrifos	e.g. Equity	Moderately harmful (up to 3 days)	Harmful (6-8 weeks)	Harmful (up to 5 weeks)	aphids
clofentezine	Apollo 50SC	Safe	Safe	Safe	Spider mite
Cyprodonil/ fludioxonil	Switch	Slightly harmful (? Days)	No information suspected to be slightly harmful	Harmful (? Days)	Botrytis
deltamethrin	Decis	Harmful (> 8 weeks)	Harmful (> 8 weeks)	Harmful (> 8 weeks)	aphids
etoxazole	Borneo	Harmful (4-8 weeks)	Suspected to be harmful for >4 weeks	No info.	spider mite
fenhexamid	Teldor	Slightly harmful (? days)	Slightly harmful (? days)	Slightly harmful	Botrytis
fenpropimorph	Corbel	Slightly harmful	No information	Safe to adults, slightly harmful to nymphs	mildew
iprodione	Rovral WP	safe	safe	Safe to adults and nymphs	Botrytis
lambda cyhalothrin	Hallmark	Harmful (> 8 weeks)	Harmful (> 8 weeks)	Harmful (> 8 weeks)	Capsids
maltodextrin	Majestik	Harmful until spray residue dry	Harmful until spray residue dry	Harmful until spray residue dry	Spider mite, whitefly, aphids
mepanipyrim	Frupica	Slightly harmful (? days)	No information	Safe to adults and nymphs	Botrytis
myclobutanil	Systhane 20EW	Safe	No information	Safe to adults and nymphs	mildew

Active ingredient	Typical product	*Phytoseiulus persimilis*	*Neoseiulus cucumeris*	*Orius laevigatus*	Target pest/ disease
pirimicarb	Aphox	Slightly harmful (3 days)	Moderately harmful (3 days).	Slightly harmful (5 days)	Aphids
pymetrozine	Chess/ Plenum	Slightly harmful (? days)	Safe	Slightly harmful (up to 2 weeks)	Aphids, capsids
pyrethrum	Pyrethrum 5 EC	Harmful (up to1 week)	Harmful (up to 1 week)	Harmful (up to 1 week)	Aphids, caterpillar, thrips
pyrimethanil	Scala	Safe	safe	Safe	Botrytis
quinoxyfen	Fortress	No information	No information	No information	Mildew
spinosad	Tracer	Slightly harmful (1 week)	Harmful (1-2 weeks)	Harmful (1-2 weeks)	Thrips
Sulphur (spray)	Kumulus DF	Moderately harmful (? Days)	Slightly harmful (3 Days)	Slightly harmful (? days)	Mildew
tebufenpyrad	Masai	Harmful (1-2 wks)	Harmful (? Days)	Harmful (2-3 weeks)	Spider mite
thiacloprid	Calypso	Moderately harmful (2 weeks)	Moderately harmful (up to 2 weeks)	Harmful (2 weeks)	Aphids, blossom weevil, capsids

Safe: kills<25%

Slightly harmful: kills 25-50%
Moderately harmful: kills 50-75%
Harmful: kills >75%
(Persistence against biocontrols given in brackets)

These data have been extracted and updated from a table produced by Jude Bennison (ADAS, by kind permission) in the HDC grower guide 'Biocontrol in soft fruit'. The data were originally sourced from biocontrol company websites:

http://www.biobest.be (Biobest also provide a helpful phone app)
http://www.koppert.com (Koppert also provide a simplified version for mobile phones)

Appendix 3 - Selected pesticides and week numbers applied up to the end of July

Field No.	Teldor	Switch	Chess	Floramite	Aphox	Calypso	Majestik	Pyrethrum 5EC	Masai	Tracer	Dynamec	Equity	Hallmark	Decis	Borneo
Fields where thrips control was successful															
1	16 21		16 23		16 17										
2	27	20				22				26					
3	27	20	18 19		17 18 19	25				25 27	17				
4	25					25 28									
5		22			16						14				
6	21				18	13 15			13						
Fields where thrips control broke down															
7	16 18 22 25	20	23		17	22		24 24		32	14				25
8	20	14 17			16	14 17			18	25 25 27			15		
9	20	21		20		24			18	20 24 25 27					
10	19 23 26	14 16			14	14				27	27			27	
11	23 26 28	23		14					23	26 27 28 29		13			
12				21		27	24 26 28	29		23 29		31			