Grower Summary

Improving integrated pest management in soft fruit crops

SF 174

Final report

Project title:	Improving integrated pest management in soft fruit crops.
Project number:	SF 174
Project leader:	Michelle Fountain, NIAB EMR
Report:	Final Report, March 2023
Previous report:	Annual report, March 2022
Key staff:	Bethan Shaw, Adam Walker, Francis Wamonje, Celine Silva, Jonah Bubb, Ben Brough, Francesca Elliott, Zoe Clarke, Greg Deakin, David Harbour, Rebecca Channon, Sam De St Croix, Aidan Wickens (NIAB EMR); David Hall, Dudley Farman (NRI); Jude Bennison, Andrew Gladman, Peter Seymour, Elysia Bartel (ADAS); Gaynor Malloch; Ailsa Smith; Carolyn Mitchell; Ali Karley (JHI) **Advisors:** William Kirk (Keele University), Tom Pope (HAU), Janet Allen (ADAS), Clare Sampson (Russell IPM), Caroline Reid (Bioline Agrosciences)
Location of project:	NIAB East Malling, growers' holdings
Industry Representative:	**Chairman:** Stephen McGuffie **Industry representatives:** Andrey Ivanov, Steve Greenaway, Cristian Marmandiu, Richard Harnden
Date project commenced:	01 April 2020

DISCLAIMER

While the Agriculture and Horticulture Development Board seeks to ensure that the information contained within this document is accurate at the time of printing, no warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Michelle Fountain

Deputy Head of Pest and Pathogen Ecology

NIAB East Malling, New Road, East Malling, Kent ME19 6BJ

Signature: Michelle T Fountain................................ Date

Stephen McGuffie

[Position]

[Organisation]

Signature .... Date ....

Report authorised by:

Debbie Wilson

Senior Research and Knowledge Exchange Manger

AHDB

Signature .... Date ....26/04/23....................................

GROWER SUMMARY

The UK soft fruit industry is experiencing a period of change which offers opportunities for new and novel pest control options. Uncertain pesticide approvals, losses of actives (and associated insecticide resistance), emerging and invasive pests, labour shortages, and climate change offer the industry an opportunity to explore and exploit high-tech, non-pesticide control methods. These will span cultural to bio-control products for integration into pest management strategies for long lasting control, building up resilience through conservation biology and augmented applications of natural enemies.

Our project covers a range of strategies targeted at key pests identified by AHDB soft fruit panel including capsids, thrips, early-season aphids, and midges. We offer testing and integrating of solutions that are often applicable across the range of soft fruit crops, including cane fruits, strawberries and blueberries and consider control measures being applied for spotted wing drosophila (SWD).

In this project we 1) researched and reported new and emerging pests which pose a future threat to UK soft fruit production informing the industry ahead of potential pest outbreaks, allowing better preparation for prevention and control options; 2) tested the efficacy of the repellent successfully used in strawberry to control capsid in cane fruit and optimise the dispensing method for the repellent compound; 3) investigated the ability of Orius to predate the capsid juvenile stages for use under warmer, summer, temperatures; 4) determined whether early season aphids can be kept in check with a novel biocontrol strategy utilising mass releases of hoverflies with semiochemical attractants for retention in the crop; 5) determined winter survival of parasitoids in aphids in strawberry crops and how insecticide use in the autumn and spring can be adjusted to protect these key natural enemies; 6) gained scientific data on efficacy of floral margins on soft fruit crop protection and potential to harbour pest species to inform growers on sowings; 7) pilot tested a ‘push-pull’ method to prevent non-western flower thrips entering strawberry crops and causing fruit damage; 8) developed a culturing method for thrips so that cost effective experiments can be done to understand the biology, damage and control strategies for future use and, finally; 9) field tested a semiochemical push pull strategy of control of midges in cane fruit.

This final report includes Grower Summaries on all the work done in the three years with a Science Section containing the detail of research in 2022. Previous Science Sections are in the first- and second-year reports.

WP1. Identify and report new and emerging pests which pose a future threat to UK soft fruit production (Year 1-2, Lead; NIAB EMR, Contributors; ADAS, JHI, NRI)

Headline

A range of future potential pest threats to the soft fruit industry have been identified.

Background

Whilst there continues to be successes in pest control strategies, changing climate (Sharma 2016; Taylor et al. 2018), the introduction of invasive pests into new territories (Early et al. 2016) and resistance to a declining selection of Plant Protection Products (PPPs) (Lamichhane et al. 2016) raises new challenges for food production. It is estimated that arthropod pests destroy up to >20% of annual crop production worldwide, at a value of more than US$470 billion (Fried et al. 2017; Sharma et al. 2017; Savary et al., 2019). In the last decade, in the UK, growers of soft fruit crops have been required to shift from the use of broad-spectrum PPPs to fewer selective PPPs combined with biopesticides, augmented and conservation biocontrol, cultural practices and novel semiochemical manipulation of insect pest populations to reduce the incidence and damage caused by pests. However, the removal of some broad-spectrum PPPs in combination with a warmer and more unpredictable climate can result in higher populations and unpredictable outbreaks of familiar and native, and non-native species (Hulme 2016). Increased movement of plant material around the globe in recent decades (Chapman et al. 2017) also leaves UK fruit production vulnerable to new pests, which often thrive in the extended season and warmer temperatures created by protected cropping. Hence, new monitoring tools for both arthropod pests and their natural enemies are needed in combination with new, less environmentally damaging approaches that can be integrated, but not at the detriment of other pest outbreaks. The reduced range of PPPs inevitably results in the same products being applied to crops sequentially, hence other control measures are needed which can be interspersed with remaining conventional PPPs, but which have different modes of action to reduce the occurrence of resistance to remaining products.

In 2020 the SF 174 team attended national and international meetings to report back potential new and invasive pests of soft fruit crops. This has been summarised in the tables, and selected references and web links). There has been liaison with AHDB, Fera, Animal and Plant Health Agency, RHS, and EPPO and CABI databases have been searched to identify and alert growers and agronomists to potential new pest problems.

Future potential pest threats to the UK soft fruit industry are summarised in tables in the report, including their, Species / Common name, Geographic distribution, Hosts / Crops, Symptoms, Description, Control used in other parts of world, Monitoring, and potential Risk for soft fruit.

Threats include three species of thrips; Japanese flower thrips, and flower thrips, chilli thrips, a true bug; Brown Marmorated Stink Bug, a whitefly; honeysuckle whitefly, a scale insect; white peach scale, two beetles; Japanese flower beetle, whitefringed weevil and several tortix moths; strawberry tortrix, *Blastobasis*, lesser apple leaf-folder, *Acleris nishidai*, *Acleris fimbriana*, yellow tortrix moth and snowy-shouldered acleris moth. In addition, a spider mite threatens to cause damage in glasshouse crops; *Tetranychus mexicanus*. Details of useful literature including links to keys are also included. Another beetle species has been raised as a potential concern, but little information has been found on this to date (*Anthonomus bisnignifer*). For species names, see full tables in main report.

In 2021 we also met with Wageningen scientists to discuss progress with Brown Marmorated Stink Bug research and attended various on-line conferences where we were made aware of additional potential future pest threats to the soft fruit industry. Summary tables in the main report were updated with the latest scientific information and another beetle species has been raised as a potential concern, but little information has been found on this to date (*Anthonomus bisnignifer*).

Concern was raised on pests of hedgerows/ windbreaks in the UK. Alder leaf beetle which causes defoliation of *Alnus incana* & *A. glutinosa* windbreaks and has also been seen on *Populus* TX 32 windbreaks surrounding soft fruit & vegetable crops at site near Worthing. Other hedgerow pests of note include woolly beech aphid (*Phyllaphis fagi*), scale insects such as Euonymus scale (*Unaspis euonymi*), beech scale or felted beech coccus (*Cryptococcus fagi*), vine weevil (*Otiorhynchus sulcatus*), winter moth caterpillars and beech red spider mite (*Eotetranychus fagi*).

Summary

Future potential pest threats to the UK soft fruit industry include;

1. three species of thrips; Japanese flower thrips, Taiwanese flower thrips and Chilli thrips
2. two true bugs; Brown Marmorated Stink Bug and Yellow Spotted Stink Bug
3. a whitefly; honeysuckle whitefly,
4. three scale insects; white peach scale, Indian wax scale, and tortoise wax scale,

5. six beetles; Japanese flower beetle, whitefringed weevil, citrus longhorn beetle, tortoise beetle, peach red necked longhorn, and *Anthonomus bisnignifer* - a species raised as a potential concern, but little information has been found on this to date
6. several tortix moths; strawberry tortrix, *Blastobasis*, lesser apple leaf-folder, *Acleris nishidai, Acleris fimbriana,* yellow tortrix moth and snowy-shouldered acleris moth, and
7. a spider mite, *Tetranychus mexicanus*.

Financial Benefits

Native and non-native pests are increasing due to increased transport of goods globally and fewer approved broad-spectrum products. These are likely to have financial impact on fruit growers.

Action Points

- Growers and their agronomists should be vigilant to new pests in the UK
- All imported plant material should be isolated and rigorously checked before planting
- Non-native species should be reported to plant health https://www.gov.uk/government/organisations/animal-and-plant-health-agency/about/access-and-opening
- Note that information in this report was correct at the time of writing.
- All control options should be checked with a BASIS qualified adviser.

Task 2.2. Dose and method of deployment of capsid repellent in strawberry and cane fruit (Year 1-2, Lead; NIAB EMR, Contributors; NRI, Russell IPM)

Headline

A product (Lybolty) developed in this project has been commercialised by Russell IPM to repel capsids from crops.

Background

In previous work under SF156, successful control of European tarnished plant bug, *Lygus rugulipennis,* was achieved in strawberry in two years of replicated field trials using a push-pull approach based on synthetic semiochemicals (Fountain et al. 2021).

The repellent "push" component, hexyl butyrate (HB), is a component of the sex pheromone of several *Lygus* species. To date, monitoring crops containing the HB repellent has not revealed any adverse effects on natural enemies.

Various blends of hexyl butyrate were formulated in blister packs by Russell IPM and their release rates and longevity evaluated in the laboratory at NRI. A blister-pack formulation of hexyl butyrate was selected having similar release rate to the NRI polyethylene sachets used in all previous trials. However, the lifetime of these formulations was less than two weeks at 27°C and 8 km/h windspeed. Russell IPM polyethylene sachet formulations based on their commercial "Dismate" formulations were evaluated, and a thick-wall formulation was developed with satisfactory release rate and lifetime of over five weeks under laboratory conditions. Formulations of HB were optimised through laboratory release rate measurements with the aim of developing a suitable formulation(s) for evaluation in field trials during 2021. Results produced two HB dispensers both providing a convenient formulation of HB; 1) a blister pack (Russell IPM) and 2) a "thick-wall" polyethylene sachet (Russell IPM). The current commercial product is a wax-like disk.

Summary

Between June and September 2020, a field trial was done in a raspberry plantation in Kent with a known history of capsid damage to fruits and foliage. The objective was to generate data to demonstrate that the semiochemical push could control capsids in cane fruits. The push was the standard formulation used in push-pull trials in commercial strawberry 2017 and

2019. The raspberry plantation was divided into 6 replicates, each divided into the following 3 equal sized plots to test two methods of deploying the semiochemical push; 1) capsid repellent sachets deployed every 2 m along the row at 1 m height, 2) capsid repellent sachets deployed every 2 m along the row, but at alternating staggered heights 0.5, 1.0 and 1.5 m, compared to 3) an untreated control. We also tested whether the semiochemical push had side effects on numbers of beneficials or caused phytotoxicity to raspberry plants.

Fortnightly assessments were made in all plots. Assessments per plot consisted of 1) tap samples of 100 young lateral stems, counting capsids and beneficials, 2) damage assessments of approximately 100 raspberries, 3) damage assessments of approximately 100 young leaves, and 4) a phytotoxicity assessment after 1 month attachment of the repellent to young lateral stems.

Both push treatments significantly reduced numbers of capsids in the crop, and damage to fruit and young leaves. Treatments had no clear adverse effect on numbers of beneficials counted in the crop, due to low numbers sampled, hence this may need further investigation. However, previously in strawberry, push-pull treatments had no adverse effect on numbers of beneficials counted in the crop. The repellent did not cause any detectable phytotoxic effects to the raspberry plants.

The aim of the field trial in 2021 was to test increasing the spacing of the HB dispensers in the crop from the standard 2 m spacing, to further reduce cost whilst maintaining control of capsids by deterring them from crops.

The trial was carried out by NIAB East Malling on commercial strawberry crops at five locations in Kent. Previous HB dispenser spacings (2 m) were compared to lower densities (5 m and 20 m). Russell IPM blister packs were used during the first two weeks and the polyethylene sachets during the next four weeks.

Numbers of both capsid nymphs and adults were lower in the treatment plots overall compared to numbers in untreated plots. However, capsids were less abundant than in previous years and there were no significant treatment effects. Damage was also low with no significant treatment effects. There were no detectable effects of the treatments on numbers of beneficials in the plots and the formulations showed no phytotoxic effects, so this approach is compatible with IPM strategies.

Financial Benefits

L. rugulipennis causes damage in raspberry and *L. pabulinus* terminates fruiting laterals in this crop (Cross 2004). Up to 100% of fruit can become downgraded because of capsid damage to raspberry. Capsid bugs can also taint the fruit with their odour. During the trial in

2020, we observed an 8% increase in undamaged fruit where the push was applied compared to untreated plots. *L. pabulinus* is also a damaging pest of blackcurrant, apple, pear and cherry. Recent changes to PPP approvals have seen registration withdrawal for key capsid controlling products in the EU, including the broad-spectrum organophosphate chlorpyrifos, and more recently, the neonicotinoid thiacloprid. This repellent strategy offers a comparable alternative to PPPs and is IPM compatible.

A commercial formulation of the capsid repellent has been developed that lasts for at least five weeks compared with the two weeks of previous formulations. Increasing the spacing of the dispensers from 2 m to 5 m or 20 m would decrease cost by 6-fold and 100-fold respectively.

Action Points

- Monitor for capsids around the crop from spring:
    - For *L. rugulipennis* use a standard green bucket trap (Unitrap) with green cross-vanes (no bee excluder grid) baited with synthetic attractants and water with a drop of detergent as a drowning solution
    - For *L. pabulinus* use a blue sticky trap baited with synthetic attractants
- *L. rugulipennis* overwinter as adults in weeds surrounding soft fruit crops, breeding in spring and then adult offspring migrate into crops late June/early July
- *L. pabulinus* overwinter as eggs in young shoots of various shrubs and trees. Nymphs of the first generation emerge in April or May
- Management of weeds that host capsids in and around the crop is recommended. Weed hosts include groundsel, mayweed, fat-hen, nettle, dock and common mugwort
- Weedy areas could be replaced with perennial wildflowers which host a range of natural enemies and pollinators important to fruit crops and can outcompete undesirable weeds (SF 174)
- Contact Russell IPM for more information on the repellent https://russellipm.com/contact/
- Growers are encouraged to trial the commercial product on crops where capsids are known to cause damage.

Task 2.3. Ability of *Orius* to predate the capsid, *Lygus rugulipennis* juvenile stages (Year 1, Lead; NIAB EMR)

Headlines

Laboratory experiments in year one showed increased mortality of *Lygus rugulipennis* in the presence of *Orius laevigatus*.

In the second year (2022), there was no reduction in damage to strawberry fruits by *L. rugulipennis* where Orius was introduced onto strawberry plants.

The presence of an alternative prey species, Western flower thrips *F.* occidentalis, also had no measurable impact on the predation Orius on *L. rugulipennis* or subsequent fruit damage.

Background and expected deliverables

Capsids, such as the European Tarnished Plant Bug (*Lygus rugulipennis* Poppius), cause direct crop damage by feeding on developing fruits (Easterbrook, 2000). This results in deformation known as 'cat-facing', making the fruit unmarketable. Chemical Plant Protection Products (cPPP) are typically relied on to supress capsid populations. However, conventional use of broad-spectrum insecticides for capsid control may disrupt biological-based Integrated Pest Management strategies used for other major soft fruit pests, such as Western Flower Thrips (WFT - *Frankliniella occidentalis*).

Anecdotal information from growers indicates that the presence of *Orius laevigatus* (Say), used to control WFT in the summer months, may also reduce capsid numbers. This was supported by data collected in project SF 174 in which fewer *L. rugulipennis* were found in tap samples where *Orius* were also collected.

The purpose of this trial was to investigate the possible role of *Orius* in *Lygus* predation in soft fruit crops, and specifically to determine the ability of *Orius* to predate on *L. rugulipennis* and ability to reduce fruit damage. In the first year of the study, laboratory-based bioassays assessed the impact *Orius* adults and nymphs had on juvenile *Lygus* stages. Wild caught *Lygus* adults were used to establish breeding cultures. Green beans containing *Lygus* eggs were offered to *Orius* for several days and the number of nymphs that emerged were counted. *Orius* behaviour was also observed using an insect-tracking software (EthoVision) in the presence of *Lygus* exposed green beans (containing *Lygus* eggs) compared to untreated green beans. The amount of time spent in the vicinity of the 2 bean treatments was recorded. Nymph predation assessments were conducted over 24- and 72-hours in which different *Lygus* nymph instars were exposed to *Orius* and mortality was compared to untreated controls.

There was a reduction in emergence of *Lygus* nymphs from eggs exposed to *Orius* although this was not significant. From the insect-tracking software, *Orius* spent more time in the vicinity of green beans that contained *Lygus* eggs than those that did not. There was a significantly higher probability of *Lygus* nymph death at both 24- and 72-hours of exposure to *Orius* regardless of *Lygus* instar in comparison to the control. For both 24- and 72-hour exposures there was a 17 and 18% probability of *Lygus* death in the *Orius* treatments (regardless of *Lygus* instar and *Orius* stage) compared to <0.01 and 0.02% in the controls respectively.

The second year of this project aimed to evaluate the impact of *O. laevigatus* on *L. rugulipennis* numbers and damage in a semi-field setting, more realistic, environment. In addition, the impact of *L. rugulipennis* predation in the presence of an alternative prey source, *F. occidentalis,* was also assessed.

Summary of the project and main conclusions

Cages housing four potted strawberry plants were inoculated with female *L. rugulipennis* and/or *F. occidentalis*. The number of pests and subsequent damage was assessed in the presence or absence of *O. laevigatus* over a period of 6 weeks. Applications of *O. laevigatus* did not reduce numbers of *L. rugulipennis* and did not reduce numbers of damaged fruit compared to untreated (no *Orius*) equivalents. The presence of an alternative prey, *F. occidentalis*, did not have a noticeable effect. It is possible that high temperatures in 2022 during the trial (up to 43°C) impacted the experiment or that *Orius* in caged strawberry plants compared to individual insects in Petri dish did not predate *Lygus*.

Action points for growers

- Although no influence of *O. laevigatus* on *L. rugulipennis* was found in the one year experiment on strawberry plants, it is recommended to release the predator for control of *F. occidentalis* in warmer summer temperatures.

Task 3.1. Promoting the control of early aphid in strawberry by augmenting and retaining aphidophagous hoverflies in the crop (Year 1/2, Lead; NIAB EMR, Contributors; NRI, Russell IPM, Koppert UK

Headline

- Synthetic hoverfly lures (including the commercial standard MagiPal^{TM}) deployed in strawberry crops attracted wild aphid feeding hoverflies and possibly helped to retain commercially released *S. rueppellii*.
- Where there were substantial aphid colonies, higher numbers of the commercially released hoverfly (*S. rueppellii*) were observed. This indicates hoverflies should probably be released once aphid numbers build up because hoverflies are unlikely to lay eggs in small aphid colonies.

Background

Early season control of aphids in strawberry (particularly potato aphid, *Macrosiphum euphorbiae*) has become difficult to achieve in recent years partly due to a reduction in chemical plant protection products and a need for suitable alternatives.

Hoverflies (Family: Syrphidae) are important predators of aphids. Adults have a high fecundity and larvae are voracious predators. However, naturally occurring hoverflies often only migrate into crops as pest populations increase, and thus too late in the season to prevent damaging populations of the pest from occurring.

Herbivore-induced plant volatiles (HIPVs), such as methyl salicylate, can be formulated into commercially available lures to attract beneficial insects, including hoverflies, into crops. Moreover, the addition of other HIPV's, has been shown to increase hoverfly numbers, demonstrating there is considerable potential to improve the attractiveness of commercially available lures using readily available chemicals, with the added benefit that such lures do not require regulatory approval. Added to this, at least three companies have been successful in mass producing hoverflies for release in commercial crops.

During 2021, a field trial was done in polytunnel grown June bearer strawberry, to test whether deployments of aphidophagous hoverflies could reduce populations of aphids (*M. euphorbiae*) early in the spring and whether this interaction could be enhanced using 2 types of hoverfly attractant to retain aphidophagous hoverflies in the crops. The trial was set up mid-April 2021 (after the aphid clean-up spray) in 4 replicate strawberry crops in Kent and ended early-June. Strawberries were June bearer varieties grown conventionally on tabletops in polytunnels. Each replicate crop was divided into 4 plots; 1) control (untreated), 2) hoverfly release only, 3) hoverfly release plus MagiPal™ lure, 4) hoverfly release plus NRI modified lure. Plots were mostly in the centre of separate strawberry fields to avoid hoverfly migration out of plots.

Seven days after, hoverflies (*Episyrphus balteatus*), in-kind contribution of Jasper Hubert at Koppert UK Ltd), were deployed in treated plots, sentinel strawberry plants infested with equal numbers of *M. euphorbiae* aphids*,* were deployed in all plots to attract hoverfly egg laying and compare subsequent aphidophagy between treatments. Plants were returned to NIAB East Malling and aphid and hoverfly life stages counted during 3 weeks incubation.

Trial findings were inconclusive and did not show enhanced aphidophagy in strawberry early in the season. Numbers of hoverfly and aphid counted on sentinel plants after field deployment were highly variable, possibly because plants were on the ground where other predators (e.g. Carabidae) may have reduced aphid numbers on sentinel plants. However, there was some evidence to suggest that hoverfly activity was positively correlated to aphid abundance. Most other arthropods recorded on sentinel plants were parasitoids (indicated by mummified aphid and adult parasitoids), but we found no clear treatment effect, due to numbers being low and variable between plots.

In 2022, we aimed to test whether 1) which volatile organic compounds (VOCs) are most attractive to natural aphidophagous hoverflies and other natural enemies in strawberry crops, and 2) investigate if a commercially available attractant (MagiPal™) could retain commercially produced hoverflies and attract natural aphidophagous hoverflies and other natural enemies into strawberry crops.

Summary

Between May and September 2022, two field trials were set up in polytunnel grown commercial everbearer strawberry crops with a history of high aphid numbers.

Trial 1 investigated which VOCs are most attractive to natural aphidophagous hoverflies and other natural enemies. Dispensers were formulated each containing a different VOC blend, then these were hung individually in white Delta Traps (Agralan ltd), suspended below tabletops 20 m apart. Seven days later, 5-minute crop walk surveys were done within a 10 m radius of each Delta trap and hoverflies and natural enemies observed on plants were counted. Following crop walk surveys, white sticky inserts (Agralan ltd) were placed inside Delta Traps. After 7 days sticky inserts were removed and adult hoverflies caught were identified to species (when possible) and counted. This trial was done at two different farms in May and again in July to increase the numbers of hoverfly species assessed.

Results showed almost twenty times more wild hoverfly adults were captured on sticky traps with VOCs compared to control traps without VOCs. However, VOC dispensers with blends did not improve the attraction of hoverflies in strawberry crops compared to the commercial standard dispenser. More than 50% of the hoverfly species on sticky traps were *M. mellinum* and *E. corollae*. Other species were included *E. balteatus*, *S. rueppellii*, *E. latifasciatus* and *C. festivum* in roughly equal numbers. Larvae of all species identified are aphidophagous and adults are nectar feeding. Almost 4-fold more hoverflies were present in strawberry crops in July compared to May.

Crop walk surveys did not detect an increase in numbers of adult hoverflies where VOCs were deployed. It is possible that our survey area was too small to detect differences between hoverfly numbers as these are highly mobile adult flying insects. Free-flying hoverflies in order of highest abundance were *E. corollae*, *E. balteatus*, *S. rueppellii* with very few *E. latifasciatus*. There was no evidence that our VOC treatments increased numbers of other aphid natural enemies.

The objectives of trial 2 were to investigate whether the commercially available VOC lure (MagiPal™) can retain commercially released adult *S. rueppellii* and attract natural aphidophagous hoverflies into 1 ha commercial strawberry crops and whether hoverfly releases and MagiPal™ dispensers could reduce numbers of aphids in commercial strawberry crops. The trial was limited due to its large scale across two farms and so results should be interpreted with caution.

The trial was set up in May at two farms. At each farm there were two 1 ha. strawberry crops; a ‘treated’ crop containing a grid of 100 MagiPal™ dispensers fastened to grow bags at 10 m intervals and releases of 1000 *S. rueppellii* hoverfly pupas every 4 weeks. The other crop was left as an untreated ‘control’. Every week for 11 weeks, crop walk surveys and tap samples were done within each crop and hoverflies (including the released species), aphids and natural enemies observed on plants were counted.

Crop surveys found more *S. rueppellii* in crops where they had been released and where the MagiPal™ had been installed at both farms compared to the untreated (control) crops. Numbers of other native species of adult hoverflies were higher in the treated crop than the untreated control at one farm, but lower at the other. As with trial 1, most species of wild hoverfly identified in the field at both farms were *E. corollae* and *E. balteatus*.

Results of aphid counts were inconclusive; one farm had fewer aphids in the treated crop and the other had fewer aphids in the untreated control. The same trend was observed during aphid tap sample assessments at each farm. Overall, aphid numbers per plant were higher at farm 2 than farm 1 during plant inspections and this may go some way to explaining why higher numbers of *S. rueppellii* were observed at farm 2. Female hoverflies are more likely to remain and lay eggs where there are high numbers of aphids for their offspring to feed on.

Finally, there was no evidence that MagiPal™ attracted other aphid natural enemies into the studied crops on the two farms.

Financial Benefits

None currently

- Product costs are dependent on volume; consult an advisor.
- During the trial in 2022, MagiPal™ dispensers were deployed once (late June) during the 12-week trial period, at a rate of 100 per ha, costing approximately £130-140 per ha (Based on 100 lures to the ha.) plus labour.
- *S. rueppellii* hoverfly pupae (Predanostrum 100 pupae per tube, Koppert UK Ltd) were deployed 3 times (monthly intervals) at a rate of 1000 pupae per ha, each deployment. In 2022 the price of Predanostrum (*S. rueppellii*) tube of 100 pupae was £42.98. Ten of these were deployed per ha, per release, plus labour.
- The recommended release rate for *E. baltatus* hoverfly (Syrphidend 50 pupae per tube, Koppert UK Ltd), as used during the 2021 field trial, is ~500 hoverfly pupae per ha. In 2022 the price of Syrphidend, pack of 50 pupae was £48.65. Ten of these were deployed per ha
- Labour costs should be added to these figures.

Action Points

- To increase chances of lures and hoverfly releases controlling aphid, treat strawberry crops where aphid numbers are building up and native aphid predators are low in the crop.
- To treat aphid build-ups early in the growing season, deploy *S. rueppellii* hoverfly tubes and MagiPal™ lures when mean daytime temperature exceeds 8°C and night-time is 0ºC or above, and the crop is in flower to provide pollen for hoverfly adults.
- Secure hoverfly tubes at crop height.
- Deploy 100 MagiPal™ lures per hectare in a grid pattern throughout the crop (at 10 m intervals) (Russell IPM).
- Place the lures at or above crop height (Russell IPM) (e.g. lures can be wedged between growbag and tabletop).
- Replace lures every 2-3 months, or as recommended by your advisor (Russell IPM).

- During the main growing season *S. rueppellii or E. balteatus* hoverflies can be released to control aphid and help pollinate the crop.

Tasks 3.4. Parasitoids for aphid control in overwintered protected strawberry (Lead NIAB, Contributors JHI and Harper Adams University)

Headline

Parasitoids overwinter inside aphids in strawberry crops.

It is important to know if parasitoids (mummified aphids) are present in the crop going into the winter as this can inform the need to release parasitoids in the spring.

This study showed that the diversity of aphids and parasitoids was not what we predicted and hence more research is needed to understand the increasing complexity of these pest and natural enemies in modern strawberry crops.

Background

Early season control of aphids in strawberry (particularly potato aphid, *Macrosiphum euphorbiae*) has become difficult to achieve in recent years. Unfortunately, potato aphid populations can persist in over-wintered crops, surviving at temperatures below freezing and continuing to grow and develop very slowly when the temperature exceeds just 1°C. With the first warmer days of spring, the aphids start to grow and reproduce much more rapidly, leading to early outbreaks and damage. The withdrawal of chlorpyrifos and thiacloprid leaves soft fruit growers with few conventional options for early season aphid control, especially when temperatures are too low for biopesticide efficacy. In addition, aphid colonies can be difficult to target with contact-acting PPPs in strawberry, early in the season, because they are often out of spray range in the crown of strawberry plants.

With limited insecticide options now available, growers are increasingly relying on releases of parasitoid wasps in early spring for aphid biocontrol. Two parasitoid species (*Aphidius ervi* and *Praon volucre*) can be particularly effective at parasitizing potato aphid. Both species are present in the mixed parasitoid products available to growers for aphid control on soft fruit (e.g., FresaProtect from Viridaxis, Aphiline Berry from Bioline, AphiScout from Koppert, etc.), and *A. ervi* is also available separately from some biocontrol companies. However, there are three main possible areas of risk and uncertainty associated with release of parasitoids for early-season aphid control:

- Failure of parasitism due to low temperature
- Impact of insecticide residues on parasitism

- Failure of parasitism due to resistance

We aim to address some of these potential risks, so that growers can be better informed in releasing parasitoids appropriately (in terms of species and timing) for effective early season biocontrol of aphids. In addition, it was observed from work in SF 156 that some parasitoids may be surviving in aphids over the winter and ready to emerge the following spring giving a head-start to biological aphid control. However, it is difficult for growers to observe this hidden biocontrol and PPP harmful to emerging parasitoids maybe applied risking early season aphid control.

Summary

Three grower's sites in Kent and Scotland were used. Strawberry tunnels were surveyed for aphid and parasitoid species on 8 occasions at regular intervals between August 2021 and June 2022. Up to 80 aphid infested leaf samples were collected per site per sampling occasion and incubated in the laboratory at 20-23°C for 3 weeks. On each assessment, and for each sample, the following was recorded: i) vegetative material sampled; ii) aphid colony size; iii) number of parasitoids emerged at 7, 14 and 21 days of incubation after collection; iv) number of mummies present; v) number of other aphid predators; and vi) taxa of aphid parasitoid.

In addition, aphids from sites 1, 2 and 3 were sampled and DNA extracted for molecular taxonomic identification. Sequences from individuals collected at sites 1 and 2 matched sequences from *Aphis fabae* (black bean aphid). The sequence generated from site 3 aphid material matched *Chaetosiphon fragaefolli* (strawberry-aphid); this was the dominant aphid species at Site 3 although *Macrosiphum euphorbiae* was also detected at low frequency.

In late March and early April 2022, the releases of a parasitoid mix were made at a rate of 0.25 parasitoids per plant, and aphids were sampled before, during and after the release period to assess the prevalence of parasitoids.

In 2021, levels of parasitism were higher in August than September and were highest at Sites 1 and 3. Numbers of parasitoids emerging between sites were variable, probably due to management practices and number of aphids present. For example, discussion with the manager of site one at the beginning of sampling revealed no insecticides had been used up to the point of first sampling.

In 2022, the levels of parasitism were low in February and increased to a maximum in early March (before parasitoid release) then slowly declined to intermediate levels in April to June. There were no significant differences in aphid abundance or parasitism level between the control plots and the treated plots. Up to 12 morphotypes of parasitoids were collected.

Parasitoids were assigned to genus following visual and molecular identification, although many samples could not be confirmed definitively, and were tentatively assigned to the genera *Dendrocerus, Kleidotoma, Praon, Lysiphlebus, Binodoxys, Aphidius* and *Aphelinu*s genera. The genera of parasitoids detected varied with the aphid species sampled on each sampling occasion.

Financial Benefits

Assessing the level of natural aphid parasitism and parasitoid activity in strawberry tunnels in early spring could help growers decide the costs/benefits of parasitoid release and the impacts of early season sprays.

Action Points

None currently.

Task 3.5. Ability of floral margins to support natural enemies and pests in proximity to soft fruit crops (Year 1-2, Lead; NIAB EMR)

Headline

Wildflower margins could be source of natural enemies and pollinators, however, impacts into tunnelled crops are minimal and sowing wildflowers inside polytunnel crops should be the focus of future research.
Numbers of thrips in wildflowers in the margins were not significant and did not appear to migrate in significant numbers into the crop.

Background and expected deliverables

Two literature reviews have been published, partly funded by the AHDB, on the impact of organic treatments and floral margins for pest and disease control in orchards (Shaw et al. 2021; Fountain 2022).

With a growing need for alternatives to plant protection products, the implementation of wildflower margins that support natural enemies is a potential contributing solution. Floral resources implemented near crops are effective in increasing the abundance of pollinators and natural enemies (Fountain 2022). The crops themselves do not provide the diversity that most natural enemies need to establish a stable and growing population throughout the year (Ramsden et al. 2017). A properly managed floral resource provides a food source for natural enemies in the form of alternative prey, pollen, and nectar, and as a shelter and overwintering habitat.

In 2019, a replicated experiment of floral margins was sown around the WET Centre at NIAB East Malling to reduce runoff from polytunnel structures but provide secondary benefits of boosting natural enemies and pollinators in the vicinity of the tunnel (Holistic Water for Horticulture, HWH). The data from the first year will be collated and funding from and Interreg-NSR, BEESPOKE project facilitated surveys of pollinating insects.

Several other research studies have implemented floral margins which are thought to benefit strawberry crops, but with very little evidence of the species or phenology of natural enemies in the crop or which flora might be attractive to crop pests. The wildflower margins, established for other projects offered an opportunity to monitor margins for beneficial and pest species of soft fruit crops including ladybirds, lacewings, and hoverflies, but also capsids, and thrips.

In this study, we aimed to;

1. Compare 3 floral treatments to an unsown control
2. Monitor the establishment and floral resource in the margins
3. Identify key natural enemies utilising floral margins
4. Identify pest species inhabiting specific flora
5. Monitor floral margins in commercial farms in the vicinity of soft fruit crops

Summary

NIAB EMR WET Centre

In 20019, the replicated plots (unsown, sainfoin, chicory, perennial meadow mix (EM1)) established around the WET Centre (strawberry crop) were surveyed for soft fruit natural enemies and pest species in May, June, July, and August. Records of vegetation cover were made in July. Floral units were identified, and invertebrates extracted using the extraction device, developed in SF 156, and ethanol extraction to monitor for thrips species that may be attracted to floral margins. Thrips adults, relevant to strawberry production, were identified to species.

<u>Floral margins</u>

All sown plots established successfully. Single species plots had more than 90% coverage of the sown species, sainfoin and chicory. The EM1 meadow seed mix covered 72% of the plots with wild carrot and common knapweed being the better-established flowering species. Single species plots like sainfoin and chicory had shorter flowering periods than unsown and EM1 plots. Longer flowering periods provided a better food and habitat resource for natural enemies and pollinators. In 2021, single species plots had > 70% coverage of the sown species, sainfoin and chicory. EM1 seed mix species covered 99% of the plots with oxeye daisy and common knapweed dominating.

<u>Arthropods in floral margins</u>

There was a higher abundance of beneficial arthropods in the margins of the strawberry crop in May and June. Floral resources were adequate in July, but some arthropod groups like beetles, ladybirds, and moths declined. This may be related to life cycle and/or dispersal away from the plots. The meadow mixture (EM1) had a higher floral resource in June. Arthropod group diversity was highest with approximately 1 specimen of each group recorded per 1.5 m^2. Chicory plots had fewer arthropods when compared with all other treatments. In August, unsown and EM1 plots were dominated by predatory spiders, and groundbugs from genus *Nysius* (not a soft fruit pest).

Herbivores in floral margins

Most arthropod herbivores or potential soft fruit pests were capsids and aphids. No strawberry pest aphids were found in the floral resources. Aphids were only present in May and June and were abundant in sainfoin plots. Capsids may have been breeding in sainfoin as higher numbers of nymphs were recorded in sainfoin in June. Most of the nymphs were Common green capsid. Numbers of herbivores declined in July. No aphids or capsid nymphs were found in July and August. Three capsid species were identified using the floral margins: Common green capsid, European tarnished plant bug, and Potato capsid. Common green capsid was in high numbers in all treatments except in chicory. The meadow mix (EM1) was less attractive to capsids than the unsown treatment.

Thrips on flower heads

Unsown species like dandelion, bindweed, hawkbit, white clover, and yarrow had, on-average, greater numbers of thrips (2 per flower head) than sown species (Park et al. 2007). In June, yarrow contained on average 5.2 ±1.0 *Thrips tabaci* per flower, known to affect soft fruit crops. White clover had 5.1 ±4.1 *Frankliniella intonsa* per flower also found on strawberry crops. Other unsown plant species had fewer than 2 thrips per flower or had thrips species not damaging to soft fruit.

In sown plots chicory, sainfoin, oxeye daisy, common knapweed and wild carrot had more than 2 thrips per flower on at least at one sampling occasion. Wild carrot had higher numbers of *Thrips tabaci* per flower head in June and July (respectively, 6.7 ±2.3 and 4.4 ±1.4). Common knapweed attracted (2.0 ±0.3) *Frankliniella occidentalis* (WFT) a known pest of strawberry crops and 2.2 ±0.6 'other' thrips not found in soft fruit crops. Overall thrips numbers declined in August.

The extraction device from project SF 156 gave very good recovery of adult thrips (at least 90%) but was less efficient at extracting larval thrips (around 50%) from flower heads.

Beneficials on flower heads

Low numbers of predatory thrips (*Aeolothrips*), parasitoids, ground beetles and *Orius* nymphs and adults were present in flowers. There was a more diverse and abundant community of pollinators in May than September, probably a reflection of floral resource. Wild bumblebees were frequent visitors to sainfoin flowers. Some bumblebee species with long-tongues prefer flowers with longer corolla flowers (Plowright et al. 1997) than those typical of strawberry flowers.

Commercial Farms

In 2021, floral margins adjacent to 2 strawberry and 2 raspberry crops were monitored. Most herbivores or potential soft fruit pests were capsids and aphids. No strawberry pest aphids were found in the floral resources. Aphids were only present in the crop from July to September and in low numbers (mean of <0.2 aphids per plant). Capsids were recorded in low numbers in the floral margins and were not analysed. No capsids of soft pests were identified in this year.

Although the number of flowering species varied between sampling dates, thrips numbers and species in each flower type (species) were consistent. Overall numbers of adult thrips in the crop were low (<1 thrips per 4 flowers). The flower margin species, with the highest numbers of WFT, was common knapweed, in August (4 thrips per flower). Numbers of onion thrips were higher in dandelion (4 thrips per flower), in June and in yarrow (3 thrips per flower), in August. Rose thrips were more abundant in strawberry in June (6 per flower), and in sainfoin (4.3 per flower) in July. Thrips in floral margins did not appear to enter crops in significant numbers at up to 50 m into the crop.

Parasitoids, spiders and anthocorids were the most abundant beneficials in the floral margins and crops.

Bumblebees and honeybees were the most common pollinators recorded with bumblebees more abundant in the floral margin, and honeybees are more abundant in the crop.

Financial Benefits

None currently

Action points

- Growers might consider implementing wildflower strips in and around soft fruit crops as part of their on-farm biodiversity deliverables.
- Supporting natural enemies and pollinators on farms will provide pollination and pest control resilience to crops.
- Once established wildflower margins may help outcompete less desirable weeds and require minimum maintenance after the second year.

WP 4 Control thrips species other than western flower thrips damaging to strawberry crops (Lead ADAS)

Headlines

- In 2020 and 2021, a push-pull method for thrips control tested at two sites did not reduce numbers of thrips per flower compared with the untreated control. Except for one individual WFT adult, thrips in flowers were species other than western flower thrips (WFT) and numbers were low despite choosing sites with a history of problems with these species.
- In 2021 and 2022, trials were done to compare the individual effects of the semiochemicals Magipal (a natural enemy attractant also reported to be a pest repellent), Lurem-TR and Thripnok (both thrips lures). In 2021, the semiochemicals were added to blue sticky traps placed above the crop and tabletops. Traps baited with Lurem-TR and Thripnok caught significantly more thrips than unbaited traps (2.8x and 1.3x respectively). Traps baited with Magipal did not catch fewer thrips than unbaited traps. In 2022, the traps were placed below the table tops and both thrips lures caught more *Frankliniella* species (1.5x) but not more *Thrips* species than unbaited traps.
- In 2022, significantly more thrips (8.1x) were caught on unbaited traps placed above the table-tops than below. Thrips species on traps above the tabletops reflected the thrips species in the flowers more closely than those below the tabletops. The predominant thrips species on traps below the tabletops were incidental cereal thrips which are not a strawberry pest.
- Low numbers of beneficial insects were caught on the ‘wet’ roller traps in the push-pull trials. In the trials testing individual semiochemicals on ‘dry’ sticky traps, those baited with Thripnok caught more bumble bees than those baited with Lurem-TR. In 2021, Thripnok and Lurem-TR traps placed above the tabletops caught 4x and 2x as many as unbaited traps respectively and in 2022, Thripnok and Lurem-TR traps placed below the table-tops caught 9x and 2x as many respectively as unbaited traps.

Background and expected deliverables

Successful IPM programmes for management of western flower thrips (WFT), *Frankliniella occidentalis* on strawberry have been developed using knowledge of its biology and behaviour. These programmes are based on the use of the predatory mites, *Neoseiulus cucumeris*, predatory bugs, *Orius laevigatus* and on some farms, ‘mass/precision monitoring’ with blue roller traps, with or without the WFT aggregation pheromone lure which can increase numbers of WFT caught. Strategies for controlling WFT on strawberry are not effective against several other species of thrips which fly in as adults and can damage fruit. The biology and behaviour of these species is not well understood. Monitoring blue sticky traps can potentially allow earlier detection of adult thrips than monitoring flowers, particularly at low densities, thus they might aid timing of control measures such as release of *Orius* or lowering thrips netting at the ends of tunnels.

This study included four trials in 2020 and 2021 testing a push-pull strategy for control of immigrant thrips adults, using Magipal™ as the 'push' and blue sticky traps with LUREM-TR as the 'pull'. Magipal™ is currently marketed as an attractant for natural enemies but has also been found to be a general pest repellent. LUREM-TR is a non-pheromone lure containing methyl isonicotinate (MI), which has been found to increase catches of 12 different species of thrips, including some that occur on strawberry i.e. WFT, the rubus thrips (*Thrips major*) and the onion thrips (*Thrips tabaci).* However, there is no published evidence that LUREM-TR attracts two other species that infest strawberry: the rose thrips, *Thrips fuscipennis* and the flower thrips, *Frankliniella intonsa*. However, it has been tested predominately in countries that lack these species.

Another thrips lure, Thripnok has recently become available and is reported to attract both WFT and onion thrips. There is no information yet on whether it attracts other strawberry pest thrips species. This study included an additional trial in 2021 comparing the individual effects of Magipal, Lurem-TR and Thripnok on thrips and beneficial insect catches on blue sticky traps. This trial was repeated in 2022, comparing Lurem-TR and Thripnok at lower thrips densities, earlier in the season than in 2021. A pilot trial was also done in 2022 comparing thrips catches on traps above or below the tabletops, as no data is currently available on optimal trap location.

Objectives

1. Test the 'push' (repellent activity) of Magipal™ on thrips adults from strawberry flowers and its attraction of thrips predators.
2. Test the 'pull' (attraction) of LUREM-TR to thrips adults on blue sticky traps and check numbers of beneficial insects caught on the traps.
3. Test the combined 'push' and 'pull' components when used together.
4. Test whether the thrips lures Lurem TR and Thripnok added to blue sticky traps increase catches of the thrips species mix that damage strawberry (*Thrips fuscipennis, Thrips major, Thrips tabaci, Frankliniella intonsa*, and WFT).

5. Test the effect of Lurem TR and Thripnok on trap catches of flying predators and pollinators when used with sticky traps mounted below strawberry tabletops – as is currently standard grower practice.
6. Test whether there is a difference in thrips sticky trap catches above or below tabletops in a commercial strawberry crop.
7. Establish a pure species laboratory culture of a *Thrips* species from strawberry flowers, to allow further work on filling key gaps in biology.

The results could potentially be used immediately by growers to aid early detection of low densities of thrips to time control methods such as release of *Orius* predators or lowering thrips netting at the ends of tunnels to reduce immigrant thrips.

The results could also be used by growers to aid mass/'precision monitoring' of thrips.

The researchers could use the results to explore further future research funding for developing improved IPM strategies for thrips management such as lure and infect, luring to trap plants etc.

Summary

Push-pull trials

In both 2020 and 2021, a push-pull method was tested at two sites. The method used the natural enemy attractant Magipal (also reported to be a pest repellent) as the 'push' and blue roller traps baited with the thrips lure Lurem-TR placed below the table-tops as the 'pull'. Despite choosing sites with a history of fruit damage by thrips species other than WFT, thrips numbers per flower were low overall in the untreated and treated plots at both sites in each of 2020 and 2021. There were no significant differences in thrips numbers or the low incidence fruit damage between untreated and push-pull treatments.

In 2020, thrips adults in flowers were predominantly *T. fuscipennis* at both sites followed by *T. major.* No WFT were seen at either site and only small numbers of *F. intonsa*. In 2021, thrips adults were predominantly *T. fuscipennis*, *T. major* and *T. tabaci* although numbers of *F. intonsa* increased at one site at the final assessment.

Low numbers of larvae were recorded in flowers in both 2020 and 2021, confirmed as *Thrips major*, *T. tabaci* and *F. intonsa.* No *T. fuscipennis* larvae were found in flowers despite this being the predominant species of thrips adults in flowers. There was no evidence that *T. fuscipennis* breeds in strawberry flowers which is a likely reason for the lack of control by *N. cucumeris*.

In 2021, the proportion of *Frankliniella* to *Thrips* species caught on the roller traps baited with Lurem-TR at both sites was higher than that recorded in the flowers. This indicated that blue roller traps baited with Lurem-TR may catch relatively more *Frankliniella* species than *Thrips* species.

Low numbers of beneficial insects were caught on the roller traps in both 2020 and 2021.

Trials testing individual semiochemicals

2021 trial

In 2021, blue traps baited with either Lurem-TR or Thripnok placed above the tabletops caught significantly more (2.8x and 1.3x respectively) adult pest thrips (*Thrips* spp. females, *Frankliniella* spp. females and males) than untreated traps. Traps with a Lurem-TR lure caught significantly more (2.1x) adult pest thrips than traps with a Thripnok lure. When comparing the catches of *Thrips* and *Frankliniella* species, Lurem-TR significantly increased trap catch of both genera relative to untreated traps and traps combined with a Thripnok or Magipal lure. Thripnok increased mean numbers of *Frankliniella* spp. adults per trap compared to untreated traps, but was significantly outperformed by Lurem-TR. Thripnok did not increase mean numbers of *Thrips* spp. per trap. Magipal did not affect mean numbers of thrips adults per trap compared with those on the untreated control traps. Of the thrips females identified to species, all the *Frankliniella* spp. on the traps were *F. intonsa* and the *Thrips* spp. were a mix of *T. fuscipennis*, *T. major* and *T. tabaci.*

Thripnok resulted in a significantly increased catch of bumble bees (4x as many as on untreated traps), however 'dry glue' traps were used in the trial which are known to catch more bees than the 'wet glue' used on roller traps. Lurem-TR and Magipal also increased mean numbers of bumble bees caught on traps (2x as many as on untreated traps) however significantly less so than Thripnok. None of the semiochemicals affected the number of predatory thrips, *Aeolothrips* spp. on the traps.

2022 trial

In 2022, flower-tapped samples revealed that *T. fuscipennis* was likely to be the most abundant thrips species at trial setup on 14 June, while at trial takedown, on 5 July, WFT was the most abundant. Numbers of *Thrips* species in flowers at take-down are likely to have been reduced by an application of lambda-cyhalothrin two days earlier. Thrips pressure in the flowers remained low throughout the monitoring period, with a mean of fewer than one adult per flower at trap take-down.

On blue traps (hung below the tabletops at the request of the steering group as this is usual commercial practice), sticky traps with either a Lurem-TR or Thripnok lure did not catch significantly more total adult pest thrips (*Frankliniella* spp. females, *Thrips* spp. females, male thrips) relative to blue sticky traps alone. When *Frankliniella* spp. females, *Thrips* spp. females, and male thrips were considered separately, significantly more *Frankliniella* spp. females were caught on traps with a Lurem-TR lure (1.49x increase) or Thripnok lure (1.46x increase) than on untreated traps. There was no significant difference seen in total 'dark' thrips species on traps between treatments, with uniformly low numbers. The most prevalent (>50%) dark thrips species seen on the traps were incidental cereal thrips (*Limothrips* spp.) No cereal thrips were found in strawberry flowers, and they are not considered to be a pest of strawberry. As in 2021, thrips species composition and abundance on traps did not match those seen in flower-tapped sample, highlighting the value of supplementing sticky trap monitoring with regular flower-tapping thrips assessments.

Relative to the 2021 semiochemical trial, total thrips catch in 2022 was markedly lower. This may have resulted from (1) The 2021 trial being undertaken later in the season (2021: 15 July – 3 August, 2022: 14 June – 5 July), (2) sticky traps in 2021 being mounted just above the strawberry crop rather than in 2022 where traps were mounted below tabletops, and (3) In 2022, flower tapping samples indicated a significantly higher number of WFT than other thrips species which may have outcompeted other pest thrips species, reducing their numbers, (4) Natural variation in thrips species incidence and numbers and (5) application of lambda-cyhalothrin two days before the traps were collected in 2022 which is likely to have killed some thrips species other than WFT.

Frankliniella species were the dominant species on traps and WFT, *Frankliniella occidentalis*, were the dominant species in flowers on the date traps were collected. Catches of predators on traps were uniformly low, with *Aeolothrips* spp., *Orius* spp., other Anthocorid spp., hoverflies, lacewings, and ladybirds averaging fewer than 0.5 per trap.

Bee catches (predominantly bumble bees) on traps was notably higher on traps relative to all other assessed beneficials, with a mean of 1.4 bees per trap on untreated traps. Significant increases in bee catch relative to the control were seen with both a Lurem-TR lure (2.2x control) and a Thripnok lure (9.4x control). Sticky traps with a Thripnok lure caught significantly more bees than sticky traps with a Lurem-TR lure – increasing catch by 4.3x. 'Dry' sticky traps were used in this trial which are reported to catch more bees than 'wet' traps which are claimed to allow some bees to escape.

Sticky traps catch of all observed beneficial groups in 2022, most notably predatory thrips (*Aeolothrips* spp.), were substantially lower than in 2021; with trap location and trial date again the factors most likely to be underlying these differences.

Trial testing traps above/below tabletops

Sticky traps mounted above the strawberry crop and the tabletops caught significantly more total strawberry pest thrips than sticky traps hung below tabletops (8.1x increase in total thrips catch). Sticky traps mounted above the crop caught a wider range of strawberry pest thrips species than sticky traps hung below strawberry tabletops (five species above, three species below). *Frankliniella intonsa* and *Thrips fuscipennis* were only detected on traps above the crop.

Below-tabletop sticky traps caught significantly more cereal thrips than above-tabletop traps (>50% of total thrips compared with approximately 7% of total thrips catch on traps above tabletops). Visual similarity of 'incidental' cereal thrips and dark pigmented pest thrips (e.g. *T. fuscipennis*, *T. major* and *F. intonsa*) may lead to inaccurate estimates of the presence and abundance of strawberry species. A notable difference was seen in *Thrips* species composition between the semiochemical trial and the above and below tabletop trial in 2022 – highlighting the potential variation in thrips species even within a block of tunnels.

Significantly more predatory thrips (*Aeolothrips* spp.) were caught on traps above the crop tabletops compared to below the tabletops. No significant differences in catches of other observed beneficial species (*Orius* spp., other Anthocorid spp., bees, hoverflies, lacewings, and ladybirds) were given on traps above and below the tabletops.

Thrips culture

In 2020, a standard laboratory method was initially tested using WFT which were successfully reared from adults to the next generation of adults on French bean pods and providing commercial bee pollen as a food source. When the same rearing system was used for *Thrips* species adults collected from strawberry flowers at Site 1 used for the push-pull trial, larvae were successfully reared on bean pods. Larvae were produced 15 days after adding the adults, whereas with WFT, larvae were produced after one week at fluctuating temperatures of 20-25°C. This indicated that the development rate of the *Thrips* species was slower than that of WFT.

However, the *Thrips* species larvae did not survive the pupal stage to produce the next generation of adults. Although the adults used to rear the larvae were not identified to species on the date of collection as we needed to keep them alive, the proportions of thrips species adults in the strawberry flowers in trial plots were 72% *T. fuscipennis*, 25% *T. major* and 3% *T. tabaci* so the adults are likely to have been one of these species.

Further work would be needed to establish a successful laboratory rearing system for a thrips species such as *T. fuscipennis*.

Action points

- Be aware that several species of thrips adults can invade everbearer strawberry crops. Species composition is likely to vary with site, season, weather and surrounding crops, hedgerow plants and weeds. Although WFT females can usually be recognized by colour, those of other, 'dark' species cannot be distinguished from each other in the field. Pest thrips species can be distinguished in the field from the larger predatory *Aeolothrips* spp. with striped wings. If identification of pest thrips species is needed e.g. to assist in the choice of plant protection product, contact an entomologist who will use a microscope and diagnostic keys.
- In the IPM programme, make regular preventive releases of *Neoseiulus cucumeris* and supplement these with releases of *Orius laevigatus* when temperatures are high enough. *Neoseiulus cucumeris* can give good control of young WFT larvae and is also known to feed on *T. tabaci* larvae. *Amblyseius swirskii* can now be used in tunnels in England and this feeds on larger WFT larvae as well as young ones but needs higher temperatures than *N. cucumeris. Orius laevigatus* is likely to feed on both adults and larvae of all pest thrips species.
- Where spray boom setup permits, prioritise the placement of monitoring sticky traps above rather than below the tabletops as these are likely to catch more thrips and a wider range of strawberry pest species more representative of those in the flowers.
- If using the thrips lures Lurem-TR or Thripnok to improve thrips detection, these may also be more effective when used with blue sticky traps located above the crop rather than below the tabletops and they may increase catches of *Frankliniella* species more than those of *Thrips* species. Be aware that both Lurem-TR but particularly Thripnok are likely to increase catches of bumble bees if using 'dry' sticky traps (those with paper that is peeled off on either side). 'Wet' traps including roller traps are claimed to trap fewer bumble bees which are reported to be able to escape from the traps, but a comparison of 'wet' and 'dry' traps was not done in this study.
- Continue to monitor thrips numbers in flowers as well as on traps. This should be done regularly, using a minimum sample of 20 flowers per crop or tunnel to estimate mean numbers of thrips per flower. Choosing upward facing, medium-aged flowers (all petals present, pollen shed, and dark anthers) will give a more reliable estimation of thrips adults than choosing young or senescent flowers.

Objective 6. To investigate the efficacy of a pheromone-based push-pull strategy for control of first-generation raspberry cane midge and blackberry leaf midge in raspberry. (ADAS and NIAB EMR)

Headline

Trials in Kent and Norfolk did not demonstrate a significant impact of pheromone push-pull strategies on raspberry cane midge.

However, there was a significant reduction in blackberry leaf midge damage to raspberry leaves and shoots in in the Kent trial and this warrants further investigation.

Background and expected deliverables

The raspberry cane midge *Resseliella theobaldi* (RCM) and blackberry leaf midge D*asineura plicatrix* (BLM) are major pests in UK raspberry production. With the loss of thiacloprid and the importance of biological control for mites in raspberry production, novel IPM strategies are required for control of these pests. Semiochemicals have been successfully used in IPM programmes to improve control of other pest species in other crops. MagiPal^{TM} sachets containing methyl salicylate, a signal molecule for systemic acquired resistance (SAR) in plants, have been used in combination with pheromone lures imbedded in roller traps. In an initial push-pull trial against the blueberry gall midge *Dasineura oxycoccana* in blueberry promising results have been obtained. This objective aims to test the efficacy of this push-pull strategy against RCM and BLM in commercial raspberry which would be compatible with IPM for other pests.

Summary

Two trial sites were established one in Kent and one in Norfolk in early spring 2021. The push (MagiPal sachets) and pull (white roller sticky traps) were deployed prior to midge detection in commercial raspberry crops. Monitoring traps were deployed to evaluate the variation in trap catches between untreated control and push-pull treated plots. Midge damage was assessed on leaves and shoots from BLM and the number of eggs and larvae of RCM present in artificially made cane splits. In Kent, significantly higher numbers of midges were caught in the control plots compared with the push-pull treated plots for both BLM and RCM. There was a significant reduction in BLM damage to leaves and shoots in two of the three assessments in the push-pull treated plots. There were significantly more RCM eggs found in green spawn

growth than in woody growth in push-pull treated plots for the first assessment. There was no overall difference in the numbers of RCM eggs and larvae between push-pull treated and control plots within artificial cane splits.

In Norfolk there was no significant difference in the monitoring trap catches of BLM, however significantly more RCM midges caught in the monitoring traps in the control plots compared with the push-pull treated plots on 24 May 2021. There was no significant difference in BLM damage to shoots or leaves between the control and treated plots. This could be because the BLM population was too low to be significantly affected. There were significantly more RCM larvae found in push-pull treated plots compared with control plots on the second assessment (24 May 2021), however larval numbers were very low. No RCM larvae were found on the first and third assessments and there was no significant difference between treatments on the fourth assessment.

Action points for growers

- Growers should continue to remove green spawn from the crop to reduce availability of preferred egg laying sites for RCM.
- Growers should continue to monitor midge emergence with pheromone lures and monitoring traps. Traps should be checked at least twice a week so that control measures can be applied at the correct time.
- Growers may want to trial the push-pull technique against BLM on their local populations.