Grower Summary

Improving integrated pest management in soft fruit crops

SF174

Annual report 2022

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DISCLAIMER

[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.]

GROWER SUMMARY

The UK soft fruit industry is experiencing a period of change which offers opportunities for new and novel pest control options. Brexit, coupled with uncertain pesticide approvals, losses of actives (and associated insecticide resistance), emerging and invasive pests, and climate change offer the industry an opportunity to explore and exploit 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 the first three years of this project we will: 1) research and report 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) test 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) investigate the ability of Orius to predate the capsid juvenile stages for use under warmer, summer, temperatures; 4) determine 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) determine 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) gain 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 test a ‘push-pull’ method to prevent non-western flower thrips entering strawberry crops and causing fruit damage; 8) develop 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 test a semiochemical push pull strategy of control of midges in cane fruit.

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). 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 (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 two species of thrips; Japanese flower thrips, and flower 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*).

Summary

In 2021 we also met with Wageningen scientists to discuss progress with Brown Marmorated Stink Bug 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 (see page 23 onwards) 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*).

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 (May 2022). 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 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 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.

Summary

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

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 2m to 5m or 20m would decrease cost by 6-fold and 100-fold respectively.

Action Points

- 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)

Headline

- Growers have reported fewer *Lygus rugulipennis* where *Orius laevigatus* have been introduced to control other pests.
- Laboratory based experiments were established to investigate *Orius* predation on *L. rugulipennis* juvenile stages.
- EthoVision tracking software was also used to monitor *Orius* behaviour in the presence of *L. rugulipennis* eggs.
- Significantly fewer *Lygus* nymphs emerged from eggs when *Orius* was present.
- Significantly higher probability of death occurred in *Lygus* nymphs when *Orius* was present.

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*) (Powell, 2019).

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 the juvenile stages of *Lygus* in the laboratory.

Summary of the project and main conclusions

Laboratory based bioassays were performed to assess the impact *Orius* adults and nymphs had on juvenile *Lygus* stages. Wild caught *Lygus* adults were used to establish breeding cultures for use in the experiments. 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 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 that had been exposed to *Orius* although this was not significant. From the EthoVision 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 death in the *Orius* treatments (regardless of *Lygus* instar and *Orius* stage) compared to <0.01 and 0.02% in the controls respectively.

Action points for growers

- *Orius* may be contributing to *Lygus* control in the field.
- Predation is low, resulting in ~17 probability of death within 24- and 72-hours of exposure.
- *Orius* predation may contribute to *Lygus* control but will not solely supress *Lygus* populations.

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

Results of this trial were inconclusive and methods for assessing the impact of hoverflies on aphids in commercial strawberry have been revised

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 conventional options 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 and have been shown 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.

Summary

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^{TM} 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 (*Epiphyas 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. After a sufficient time in the field these plants were returned to NIAB EMR and aphid and hoverfly life stages counted during 3 weeks incubation.

Trial findings were inconclusive as to whether releases of aphidophagous hoverfly can reduce *M. euphorbiae* early in the season. Therefore, we also cannot conclude whether the 2 types of hoverfly lure tested enhance aphidophagy in strawberry early in the season. Numbers of hoverfly and aphid counted on sentinel plants after field deployment were highly variable. This is possibly because plants were positioned on the ground (to be away from the crop), where other predators (e.g. Carabidae) may have reduced aphid numbers on plants.

However, there was some evidence to suggest that hoverfly activity was positively correlated to aphid abundance, as described by Hodgkiss et al. (2019). This was observed within the plot where highest numbers of *M. euphorbiae* were observed in the crop.

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 year 2, two field trials are planned for spring; 1) Trial 1 will investigate which attractant blends are most attractive to natural aphidophagous hoverflies and other natural enemies in strawberry crops, 2) Trial 2 will investigate if a commercially available attractant (MagiPal^{TM}) can retain commercially produced hoverflies and attract natural aphidophagous hoverflies and other natural enemies into strawberry crops.

Financial Benefits

None currently

Action Points

None currently.

Tasks 3.4. Parasitoids for aphid control in overwintered protected strawberry

Headline

A trial has begun to examine the overwintering ability of parasitoids in aphid in commercial 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 fewer 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), 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 are being used. Strawberry tunnels have already been surveyed for aphid and parasitoid species. A total 80 leaf samples were taken per site. Aphids were brought back to the laboratory and incubated at 20-23°C for 3 weeks. The size of the colony, parasitoids and aphid predators were recorded for each sample. Assessment of parasitoid emergence from aphids was done at 7, 14 and 21 days of incubation. On each assessment, and for each sample, the following was recorded: i) vegetative material sampled; ii) number of parasitoids emerged; iii) number of mummies present; iv) number of other aphid predators.

In addition, aphids from sites 1, 2 and 3 were sampled and DNA extracted. 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).

In 2022, there will be 2 sampling occasions between February and March before any parasitoid release. After these samplings at each farm a first release of a parasitoid mix product will be made at a rate of 0.25 parasitoids per plant, and aphids sampled on a number of occasions after for the prevenance of parasitoids.

In 2021, levels of parasitism were higher in August than September and were highest at Sites 1 and 3. Numbers of parasitoid 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.

Work on this task continues in 2022.

Financial Benefits

None currently

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 the crop 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).

Several 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, that are part of the other projects, offer an ideal opportunity to monitor margins for beneficial and pest species of soft fruit crops including ladybirds, lacewings, and hoverflies, but also capsids, and thrips.

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 have been shown to be effective in increasing the abundance of pollinators and natural enemies (Fountain 2022). 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 could provide 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 EMR 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.

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 (2021) only

Summary

NIAB EMR WET Centre

In the first year the replicated plots (unsown, sainfoin, chicory, perennial meadow mix (EM1)) established around the WET Centre (strawberry crop) at NIAB EMR in 2019 were surveyed for soft fruit natural enemies and pest species in May, June, July, and August. Records of vegetation cover were also 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.

Floral margins

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.

Arthropods in floral margins

There was a higher abundance of beneficial arthropods in the margins of the strawberry crop in May and June. Floral resources were also 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 thought to be from genus *Nysius* (not a soft fruit pest).

<u>Herbivores in floral margins</u>

Most arthropod herbivores or potential soft fruit pests found during this trial were capsids and aphids. No strawberry pest aphids were found in the floral resources. Aphids were only present in May and June and were particularly widespread in sainfoin plots. Capsid were thought to be 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 found in high numbers in all treatments except in chicory. The meadow mix (EM1) was less attractive to capsids than the unsown treatment.

<u>Thrips on flower heads</u>

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 found on soft fruit.

In sown plots chicory, sainfoin, oxeye daisy, common knapweed and wild carrot were the flowering species with more than 2 thrips per flower (Park et al. 2007) 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.

<u>Beneficials on flower heads</u>

Predatory thrips (*Aeolothrips*), parasitoids, ground beetles and *Orius* nymphs and adults were present in flower heads. No significant numbers were recorded on any plant species. There was a more diverse and abundant community of pollinators in May than September, probably a reflection of floral resource. Bumblebees were frequent visitors to sainfoin flowers, including many wild species, but more research is needed to see if commercial bumblebees are distracted by wildflower margins. 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 (average of < 0.2 aphids per plant). Capsid (mirids) were recorded in low numbers in the floral margins and were not analysed. No capsids of soft pests were identified.

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 (16 thrips per 4 flowers). Numbers of onion thrips were higher in dandelion (16 per 4 flowers), in June and in yarrow (12.1 thrips per 4 flowers), in August. Rose thrips were more abundant in strawberry in June (23.9 per 4 flowers), and in sainfoin (17.3 per 4 flowers) 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.

No significant differences in numbers of pollinator species were observed between the floral margins and distances up to 50 m into the crop. Bumblebees and honeybees were the most common pollinators recorded. However, numbers of bumblebees were higher in the floral margin, while 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 be able to 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

Headline

- Blue sticky traps baited with the thrips lures Lurem-TR or Thripnok placed just above the plants caught significantly more thrips than unbaited traps (2.8x and 1.3x respectively). Higher numbers of thrips were caught on the Lurem-TR traps than on the Thripnok traps (2.1x more).
- Blue sticky traps baited with the natural enemy attractant Magipal (also considered to be a pest repellent) did not catch fewer thrips than unbaited traps.
- Thrips species identified on the traps were a mix of *Thrips fuscipennis* (rose thrips), *Thrips major* (rubus thrips), *Thrips tabaci* (onion thrips) and *Frankliniella intonsa* (flower thrips).
- In two push-pull trials using Lurem-TR, on blue roller traps as the 'pull' and Magipal as the 'push', thrips numbers in flowers were too low to demonstrate a reduction in thrips numbers in flowers or thrips damage to fruit. Thrips adults in flowers were predominantly rose thrips, rubus thrips and onion thrips although numbers of flower thrips increased at one site at the final assessment.
- Very low numbers of thrips larvae were found in the flowers in both push-pull trials and were identified as *T. major* and *T. tabaci*.
- The proportion of *Thrips* species to *Frankliniella* species caught on the roller traps baited with Lurem-TR in both push-pull trials did not mirror that recorded in the flowers. Proportionally more *Frankliniella* species were caught on the roller traps than found in the flowers.

Background and expected deliverables

Highly 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 'mass monitoring' with blue roller traps on some farms - 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. However increasing evidence is emerging to suggest that these other species now dominate in commercial strawberry crops where WFT are controlled using IPM.

In this study two trials were done. In the first trial, a push-pull strategy was evaluated for thrips control at two sites This strategy used Magipal as the 'push' and blue roller 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 WFT, the rubus thrips (*Thrips major*) and the onion thrips (*Thrips tabaci*). However, to date there is no published evidence demonstrating that Lurem-TR attracts two other species that infest strawberry: the rose thrips, *Thrips fuscipennis* and the flower thrips, *Frankliniella intonsa*.

In the second trial, the effect of both Magipal and Lurem-TR on catches of thrips and beneficials on blue sticky traps was evaluated. A third semiochemical, Thripnok which is reported by the supplier to be an effective lure for WFT and onion thrips, was also evaluated in this trial.

The objectives of these trials were to test whether:

1. Thrips numbers per flower and fruit damage are reduced by using MagiPal (push) combined with Lurem-TR and blue roller traps (pull) compared to in control plots.
2. The roller traps used in the push-pull strategy have a negative impact on beneficials in the crop.
3. The addition of Lurem-TR, Magipal or a new kairomone lure (Thripnok) to blue monitoring traps has a significant impact on the catches of thrips and beneficials.

Summary of project and main conclusions

Push-pull trial

As in previous work in this project and in SF 156, several species of thrips adults invaded everbearer strawberry crops. Species composition is likely to vary with site, season and weather but unless WFT is present, there seems to be very little breeding in the flowers.

Thrips adult and larvae numbers per flower across both sites was low, with fewer than a mean of one thrips adult per flower across all assessments. At both sites, push-pull treatment did not result in any significant differences in the mean number of either *Thrips* spp. or *Frankliniella* spp. per flower. At both sites, *Thrips fuscipennis* and *Thrips major* were the most prevalent species in flowers. *Thrips minutissimus* was dominant on the first assessment date at site 1 but owing to the small sample size this result might be spurious. This species was found only on the first assessment date at site 1 and not at site 2.

At the final assessment, at Site 2, a markedly different thrips species mix was seen in the flowers, with *Thrips tabaci* and *Frankliniella intonsa* dominating. Only a single individual of *Frankliniella occidentalis* (WFT) was identified across both sites throughout the trials, demonstrating the continuing efficacy of WFT control within IPM. Very low numbers of larvae were recorded in the flowers, and were more numerous at site 2, where they were identified as *Thrips major* and *Thrips tabaci.*

At Site 1, fruit bronzing incidence and percentage area was minimal, with well below a mean of 1% fruit area damaged. At Site 2, fruit bronzing incidence and percentage area was notably higher, significantly increasing on the last two assessments relative to earlier assessments, reaching almost a mean of 5% fruit area damaged. No significant differences were seen in fruit bronzing incidence or percentage damage between untreated and push-pull treated blocks at either site.

The proportion of *Thrips* spp. to *Frankliniella* spp. was 3:2 on roller traps at site 1 and approximately 1:1 at site 2 on all assessment dates. However, this was not reflected in the proportions of thrips species found in the flowers. At site 1, *Frankliniella* species were absent in flowers except for very low numbers on the first assessment date. At site 2, most thrips found in flowers were *Thrips* species until the final assessment date when the proportion of *Thrips* spp. to *Frankliniella* spp. was approximately 1:1, with all the *Frankliniella* spp. identified being *F. intonsa*. These results indicated that the proportions of thrips species on roller traps baited with Lurem-TR under the table tops are not necessarily the same as those in the flowers; the roller traps may catch relatively more *Frankliniella* spp.

Numbers of bees and other beneficials on the roller traps were very low.

Semiochemical trial

Traps with either a Lurem-TR or Thripnok lure 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 (*Thrips* spp. females, *Frankliniella* spp. females and males) than traps with a Thripnok lure. Lurem-TR significantly increased trap catch of both *Thrips* spp. and *Frankliniella* spp. 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 in the semiochemical trial were *F. intonsa* (flower thrips) and the *Thrips* spp. were a mix of *T. fuscipennis* (rose thrips), *T. major* (rubus thrips), and *T. tabaci* (onion thrips).

Thripnok resulted in a significantly increased catch of bees (4x as many as on untreated traps), however 'dry glue' traps were used in the semiochemical 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 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.

Action points

- Be aware that several species of thrips adults can invade everbearer strawberry crops. Species composition is likely to vary with site, season and weather but unless WFT is present, there are few species breeding in strawberry flowers.
- 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. *Orius laevigatus* is likely to feed on both adults and larvae of all pest thrips species.
- Consider using Lurem-TR together with blue sticky traps for monitoring thrips as this may improve detection of both *Thrips* spp. and *Frankliniella* spp.
- Continue to monitor thrips numbers in flowers as well as on traps.
- Most thrips species found in strawberry flowers (except for predatory thrips) can cause fruit damage. However, if species identification is needed e.g. to assist choice of plant protection product if required, contact an entomologist.

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™ 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.

