SUSTAINABLE MANAGEMENT OF THE WESTERN FLOWER THRIPS IN STRAWBERRY CROPS

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An introduction to thrips

Thrips are an ancient order of insects (order Thysanoptera) that have been around since the time of the dinosaurs. They are so adaptable that they are found from the Arctic to the tropics, feeding on a wide range of plant, animal and fungal hosts. Thrips are small in size, typically around 2mm long, and their delicate fringed wings make them weak fliers. This makes them unlikely candidates for causing devastating crop loss, yet thrips cause billions of pounds loss to the global economy every year. The most damaging species spread plant viruses, as well as causing direct feeding damage with their piercing-sucking mouthparts. The western flower thrips (WFT, Photo 1), *Frankliniella occidentalis,* is considered the most economically damaging of these on a global scale (Mantel & Vierbergen, 1996). This article explores why WFT has become such a devastating pest in one crop (strawberry) and how it can be managed in a sustainable way.

Western flower thrips, a spreading threat

Originally from western USA, WFT has spread rapidly around the world since the 1970s. Several factors have contributed to this spread: this highly adaptable species has been recorded on over 240 host plants including over 80 crop species, so it can establish in new habitats relatively easily; its ability to break down toxins has meant that it has developed resistance to all the pesticides commonly used against it; WFT evade capture by predators and humans by hiding in small cracks and crevices, which has allowed them to spread around the world through the increasingly global plant trade (Kirk & Terry, 2003); global warming may also contribute to their gradual spread Northwards. WFT was first recorded in the UK in 1986, when it became a major pest of glasshouse crops such as cucumber, pepper and chrysanthemum. The occurrence in strawberry coincided with the increased use of polytunnels, which provide a warmer environment in which WFT thrive. At 25°C, adult WFT females have a 2-week generation time and lay about 7 eggs per day on a flowering strawberry crop (Nondillo *et al.*, 2009), so the potential for a rapid population increase is massive, and growers can lose a crop in a short time when thrips are uncontrolled. Faced with this threat, growers turned initially to chemical insecticides, but with few chemicals available and increasing levels of pesticide resistance, control broke

Photo 1. Adult and larval *Frankliniella occidentalis* (©Cattlin).

down and WFT became the most economically damaging pest of UK strawberry. Both adult and larval WFT feed on strawberry fruit, causing it to turn a bronze colour which makes it unmarketable (Photo 2). The annual loss of UK strawberry production due to WFT was estimated at 10–15%, with individual farmers losing entire crops.

Why was thrips control breaking down?

In a survey of growers, the breakdown in WFT control in UK strawberry crops could be linked to four main causes (Sampson, 2014a):

1. WFT has become resistant to all the pesticide products registered for use on strawberry.
2. There was a large carry-over of pests from the previous season in crops with poor control, either from over-wintered

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Photo 2. Waste bronzed strawberry fruit made unmarketable by WFT damage (©Irving).

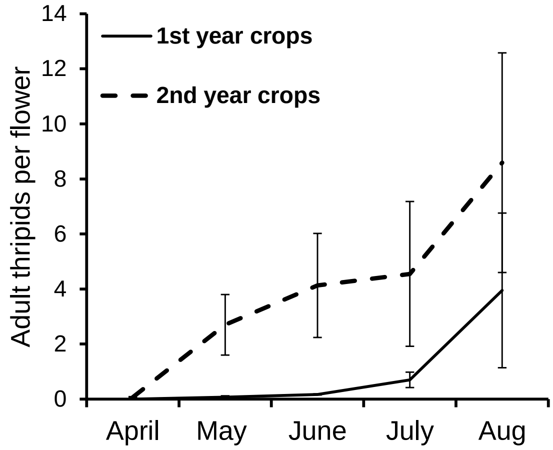

Figure 1. Mean adult thrips per flower ± SEM from samples from first- and second-year, semi-protected strawberry crops (cvs. Camarillo and Finesse, n = 3 fields) (Sampson, 2014b).

crops, or from reused, untreated growbags, resulting in damage following first-flowering.

3. Predators were released too late, or in insufficient quantities.
4. Crop protection products that are harmful to predators were used during the time when predatory mites were being used, or there was repeated use of slightly or moderately harmful pesticides, which prevented predator establishment and interrupted thrips control.

An integrated approach to thrips management

Some growers consistently manage thrips with minimal fruit damage. These growers release predatory mites routinely from flowering, and combined biological control with mass trapping in one-year crops, and are careful to avoid broad-spectrum, long-residual pesticides during the time when the predators were working. If insecticide treatment is required, these growers are careful to select products that will have limited impact on predators, then re-introduce predators after treatment. Therefore, the most effective approach to thrips control is to integrate all methods:

Cultural control – reduce carry-over of thrips between crops and over winter

A survey of thrips numbers through the year in commercial strawberry crops indicated that the carry-over of thrips from first to second-year crops resulted in more thrips in second-year crops by a factor of about 40 at the start of the season (Figure 1, Sampson, 2014b). Growing one-year crops in heavily infested fields or farms (instead of 2 or 3-year crops) can help to maintain thrips numbers at manageable levels. The carry-over of thrips from first to second-year crops may also be reduced by maintaining predator numbers after cropping has finished. Common weed hosts such as chickweed and groundsel (Photo 3) were present in all strawberry fields surveyed and these act as a green bridge from which thrips infest new crops, so good weed control can also reduce carry-over through the winter. As both adult and larval WFT were found in fields in November, growers need to maintain WFT control after cropping to reduce the carry-over to the next season.

Photo 3. Groundsel, a common WFT host found in UK strawberry fields.

Biological control – predators are the main control agents

Natural enemies are an essential part of managing pesticide-resistant WFT in strawberry. Over 300 natural enemy species of WFT have been identified and evaluated in different crops

Photo 4. The predatory mite *Neoseiulus cucumeris* (©Certis Europe B.V.).

Photo 6. Adult *Orius laevigatus* (©Certis Europe B.V.).

Photo 5. Releasing *N. cucumeris* onto a strawberry crop (©Irving).

around the world, but in practice, relatively few species are released commercially. The predatory mite *Neoseiulus cucumeris* is the most widely used predator against WFT in UK strawberry crops (Photo 4). These small predatory mites only feed on eggs and first instar larvae, so control relies on inundation of the crop with predators from first flowering (Photo 5), before thrips adult numbers build up. The predatory bugs *Orius* spp. are often used in combination with predatory mites as they are voracious predators that feed on both adult and larval WFT (Photo 6). *Orius* spp. can be very effective on strawberry and WFT populations decline sharply once flower occupation is high (Coll *et al.*, 2005), but *Orius* require warm temperatures to establish and are less effective in Northern Britain. To be effective, predators must be well distributed over the crop and in sufficient numbers to control the thrips. This can mean routine releases of 25 predatory mites per plant per fortnight where growers are also spraying pesticides, but this is still cost effective. As *N. cucumeris* also feed on pollen, they establish in the absence of thrips, and fewer predator releases are needed where pesticide use is lower. Making decisions on when to release, and how many predators to release, requires commitment to monitoring the crop to determine whether the predator and prey numbers are in balance. Confident advisers are needed, who can give the appropriate advice on what action to take accordingly.

Physical control – mass trapping reduces the threat

Integrated pest management programmes work best when a number of different control measures are combined, resulting in more robust programmes. The addition of blue sticky roller traps (Photo 7) to control programmes consistently reduces numbers of adult WFT and fruit damage. Roller traps have been developed that maximise the attraction to WFT by selecting a blue colour that is particularly attractive, adding patterns to enhance the attraction as well as incorporating the WFT aggregation pheromone, which can double the trap catch of both male and female WFT (Optiroll super plus, Russell IPM). In controlled studies, use of blue sticky roller traps alone, or with additional WFT aggregation pheromone, reduced adult thrips numbers by 61% and 73% and fruit damage by 55% and 68% respectively (Figure 2, Sampson & Kirk, 2013). The roller traps integrate well with predator use and with bumble bee pollination and did not interrupt the establishment of predatory mites, *Orius* species or affect pollination. When used in combination with predatory mites, the mites feed on thrips larvae whilst the traps catch adults which results in more effective control overall than where either method is used alone. Combining predators and sticky traps is being used routinely by some growers, who have achieved minimal thrips damage over the past five seasons. The traps also reduced numbers of other species of thrips, such as *Thrips major*, which can also cause damage to strawberry.

Photo 7. Blue sticky roller traps (Optiroll, Russell IPM) used to reduce numbers of adult thrips (©Russell IPM).

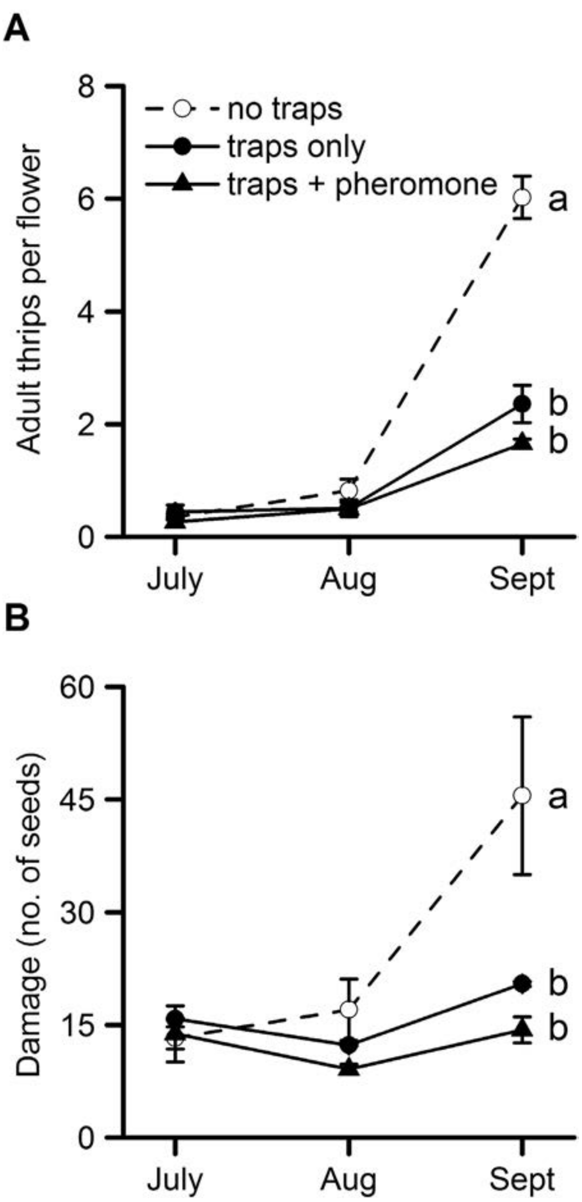

Figure 2. The effect of mass trapping with blue sticky roller traps (Optiroll, Russell IPM) on a) thrips numbers and b) fruit damage (Sampson & Kirk, 2012).

Monitoring and decision making – monitor weekly and act on what you find

Year on year records of pest populations are invaluable for decision-making, both to predict periods of risk, but also to confirm that low numbers of thrips do not cause economic crop loss when predators are well established (seeing is believing). The change from a chemically-based to a biologically-based control programme relies on knowing the relative numbers of pests and predators in a crop, and having the confidence NOT to spray when they are in balance. The first step towards improved control is to start monitoring.

When are strawberry crops most at risk?

Typically, WFT start to breed in strawberry from first flowering (e.g. early April in the UK). Everbearing crops, that flower and fruit through the summer, are more at risk than 60-day crops as they provide a continuous food-source for WFT. Typically there are large numbers of flowers in the first flush of an overwintered everbearer crop. If thrips have overwintered from the previous season, the first period of risk is at the end of this flower flush (e.g. early July) when the numbers of flower decline, forcing more thrips into fewer flowers. If uncontrolled at this stage WFT numbers continue to increase through the summer, peaking in August, then declining as temperatures decrease.

What is the economic injury level?

Economic injury levels (EILs) vary considerably for strawberry, from 3 to 24 thrips per flower, according to thrips stage monitored (i.e. adults only or adults and larvae combined), cultivar, sale price and the presence or absence of predators (Coll *et al*., 2007; Sampson & Kirk, 2016). Therefore any absolute thresholds in the literature should be tested in the growers own fields and adapted accordingly. Despite these limitations, the adoption of thresholds for timing insecticide treatments is likely to reduce the selection pressure for resistance and therefore maintain or improve the efficacy of insecticides (Denholm & Jespersen, 1998), as well as reducing the impact on natural enemies. Most thresholds developed for strawberry crops are based on assessment of thrips density in flowers, as there is a strong correlation between numbers of *F. occidentalis* per flower and fruit damage (Sampson, 2014). In UK crops, the EIL is about four adult thrips per flower in the absence of predators, but increases to over eight at densities of *N. cucumeris* typical of good establishment in crops. The EIL could be increased by about 0.7 adult thrips per flower for every *N. cucumeris* per flower (Figure 3, Sampson & Kirk, 2016). If WFT numbers exceed the EIL, the most appropriate action may be to release more predators or to use an insecticide, if an effective IPM compatible pesticide is available.

Chemical control – manage insecticide resistance, only spray when required

When faced with damaging WFT populations, growers may need to reduce WFT numbers fast to prevent loss, and chemical pesticides can be a useful tool to redress the balance. Because WFT hide away between the petals and sepals, good canopy penetration and spraying technique is essential to contact the thrips and achieve control. Spinosad is a commonly used pesticide against WFT on strawberry as it can be highly effective, has low mammalian toxicity and its use can be integrated with predatory mites. However, spinosad-resistant WFT populations were found within only three years of its commercial release in the UK and are widespread throughout the world (Sparks *et al*., 2012). So how can growers retain the use of such useful products? Resistant thrips populations compete well in the field, but tend to become diluted by more susceptible biotypes at the end of the season, so some efficacy can be retained by minimising insecticide use. Good quarantine and hygiene measures allow growers to start new crops with lower pest numbers. If biological control agents (predators and parasitoids) are used as the first choice it reduces the need for chemical pesticides. Carrying out routine monitoring and only using chemical pesticides when WFT exceeds the damage threshold

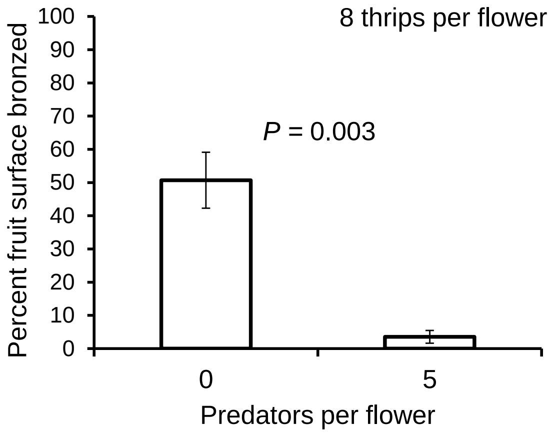

Figure 3. The mean percentage of seeds surrounded by bronzing per fruit following infestation of strawberry flowers with eight adult WFT per flower, with or without a good establishment of *N. cucumeris* (Sampson & Kirk, 2016).

reduces the use further. When a pesticide is no longer effective, growers should avoid the temptation to increase the dose and frequency of pesticide applications, instead look for alternative active ingredients from different chemical, physical or biological groups as a resistance management strategy, while being careful to avoid long-residual broad-spectrum pesticides that will kill the predators.

Challenges and new developments

More and more UK strawberry growers have adopted IPM for thrips control. In 2006, 469 UK strawberry hectares were treated with *N. cucumeris*, by 2016, 2,768 ha (65%) were treated (Garthwaite *et al.*, 2006, 2017). Successful adopters of the IPM programme outlined above can achieve WFT control with little or no fruit damage. A few growers still lose thrips control by using incompatible pesticide treatments against thrips or other pests such as spider mites (*Tetranychus urticae*), capsids (e.g. *Lygus rugulipennis*), aphids (*e.g Myzus* species) and spotted wing drosophila (*Drosophila suzukii*). Therefore control of thrips relies on adopting compatible control methods for all pests and diseases in strawberry. A variety of IPM compatible control methods are available to control these species (Saville *et al.*, 2013). Whilst effective natural enemies are available to control spider mites and aphids, this in not yet the case with spotted wing drosophila and capsids. New IPM compatible methods are currently being tested by Russell IPM against these species, including combining repellents, natural enemy attractants with pheromone trapping for capsid control (push-pull effect), the integration of biopesticides (e.g. *Metarhizium anisopliae*) to improve thrips control, and new baits, traps and attractants for spotted wing drosophila control. These offer new solutions for the future that will make IPM programmes in strawberry more sustainable to the benefit of growers, crop workers and consumers.

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