Monitoring and trapping with sticky traps, what's new?

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Monitoring pests in protected strawberry. Photo: Russell IPM

One hundred years ago, it was observed that greenhouse whiteflies, *Trialeurodes vaporariorum* (Westwood) (Hemiptera, Aleyrodidae) are particularly attracted to opaque yellow traps (Lloyd, 1921). Today, millions of sticky traps (card or plastic covered with a thin layer of a clear adhesive substance) of different colours are used worldwide. They are used for the monitoring, decision making (Böckmann *et al,* 2015), and mass trapping (Sampson and Kirk, 2013), of flying crop pests as part of Integrated Pest Management (IPM). This article explores how traps are used today, recent developments and the next steps needed to make the best use of these simple tools.

The attraction of colour

Colours are used by insect pests to locate host plants (Prokopy & Owens, 1983). Yellow traps, with high reflectance in the long-wave region from green to red (about 500-640 nm) and low reflectance in the short-wave region from UV to blue (about 300-500 nm), are particularly attractive to leaf-feeding insects, such as aphids, small flies, thrips and whiteflies (Figure 1a). Flower and fruit-visiting insects are often attracted to the colour of their host's flowers or fruit (Kirk, 1984): The spotted wing drosophila (SWD), *Drosophila suzukii,* which lays its eggs in berry fruit, has an attraction to red (Kirkpatrick et al., 2017); The western flower thrips (WFT), *Frankliniella occidentalis*, typically shows preference for blue traps (440-460nm) in greenhouse grown crops (Figure 1b).

Other features of the trap can affect trap catch, such as background, length of edge, shape, position, and surface texture (Vernon and Gillespie, 1995). Relative attraction can be affected by ambient light conditions, or be enhanced by LEDs. The selection of the best trap colour will depend on the purpose of trapping. Yellow sticky traps are a good choice for monitoring a wide range of pest species on a single trap (Figure 2a,b). Other trap colours, such as blue for thrips and capsids or red for SWD, are more appropriate when a grower is selecting traps to maximise the catch of specific species. Sometimes less attractive trap colours are selected in order to minimise the catch of non-target insects, including predators and pollinators. For example, black sticky traps (Black impact traps, Russell IPM) are combined with a species-specific pheromone to catch the marmorated stink bug, *Halyomorpha halys*. This ensures that only the target pests are caught, making the pests easier to identify and count. Sticky traps are available with different

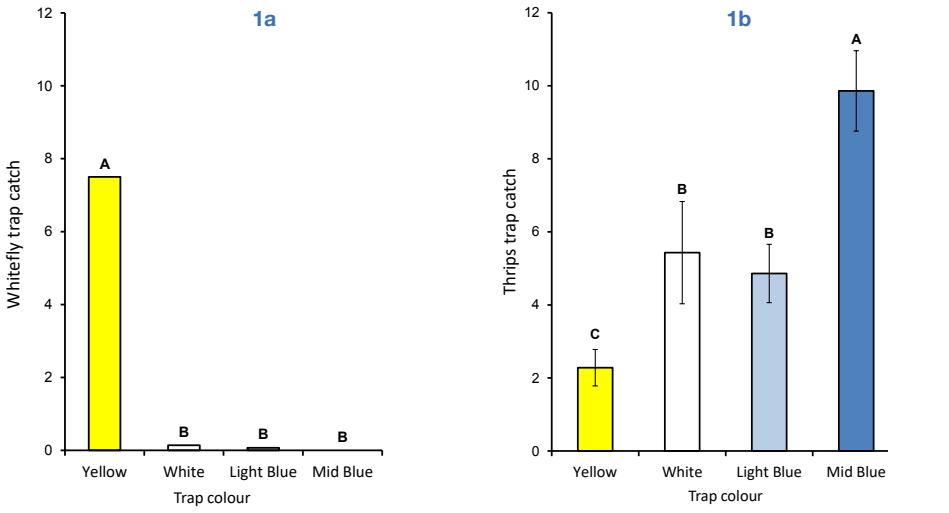

Figure 1. Mean trap catch ± S.E. of a) *Trialeurodes vaporariorum* and b) *Frankliniella occidentalis* on different coloured sticky traps in glasshouse strawberry

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glue types, which affects the range of species caught. The strongest glue is sold with a peel-off silicon paper (eg Impact traps, Russell IPM), which is required to capture larger species such as marmorated stink bug. Traps are also available with tacky 'wet' glue which retain high catch rates of small pest species, such as whiteflies, but from which larger species can escape (eg Hytak traps, Russell IPM). These are used to reduce by-catch of some of the larger predators and pollinators, such as lacewings, *Orius* and bees.

Enhancing trap catch

Insect behaviour is partly controlled by semiochemicals (scents), such as pheromones, kairomones and their analogues, which are used to locate mates and plant hosts. These can be added to sticky traps to increase trap catch. The scents can be added as individual lures, or encapsulated for longer release and added to the glue within the sticky traps (eg Optiroll super plus, Russell IPM). A number of attractants, including (*E*)-2-Hexenal and 3-Hexen-1-ol and Linalool, have been identified to attract the glasshouse whitefly, yet few have been found effective in the field or developed commercially (Schlaeger *et al*, 2018). In contrast, many attractants have proved effective against WFT and a range of thrips attractants are available commercially (Kirk *et al*, 2021). In experiments in greenhouse strawberry, adding the aggregation pheromone, neryl (*S*)-methyl butanoate (Thripline AMS, Bioline Agrosciences), the kairomone analogue methyl isonicotinate (Lurem-T, Koppert) and a mix of floral scents (Thripnok, Russell IPM) to yellow sticky traps, enhanced trap catch of the western flower thrips, by 50-300% (Figure 3). The best choice of attractant will depend on the crop and thrips species present. Whereas the western flower thrips aggregation pheromone is highly specific to WFT, kairomones and their analogues are more generally attractive to a range of flower-inhabiting thrips species. A range of lures are available for different pest species. In raspberry, adding a fruit volatile lure (SWD lure, Russell IPM) to red sticky traps increased trap catch of spotted wing drosophila by x46, making the trap and lure combinations a convenient and sensitive monitoring tool (Figure 4).

Monitoring & decision making

Understanding when a crop is at risk and the pest numbers that cause crop damage is essential in order to determine when and whether intervention is required, so the first step towards improved control is to start monitoring. For monitoring, growers are looking for a consistent standard against which to measure daily and annual fluctuations of pest and beneficial insects, rather than selecting traps with the highest catch. Yellow traps are most commonly used because of their attraction to a wide range of species. It also helps that most insects are easier to see against a yellow background than on darker trap colours. Typically, sticky traps are hung vertically just above the crop canopy at a density of about one trap per 200 m^2 (Figure 2a). They should be moved up gradually as the crop grows to retain the same height above the crops. Trap catch of whiteflies and their parasitoid, *Encarsia formosa*, have been shown to correlate well with corresponding numbers in tomato crops within 170 m^2 plots (Böckmann *et al,* 2015). For monitoring some pests, such as fungus gnats, *Bradysia* spp., traps catch more insects if placed horizontally on the ground near the growing media, as adults emerge from the soil and are poor fliers, and are less common at the top of tall plants.

Year on year records of pest populations are invaluable for decision-making, both to predict periods of risk and to determine the threshold number of pests that cause economic damage. Damage thresholds can ➜

Figure 2. a) Monitoring pests using yellow sticky traps in glasshouse chrysanthemum
b) glasshouse whitefly caught on yellow sticky trap (Impact trap, Russell IPM). Photos: Russell IPM

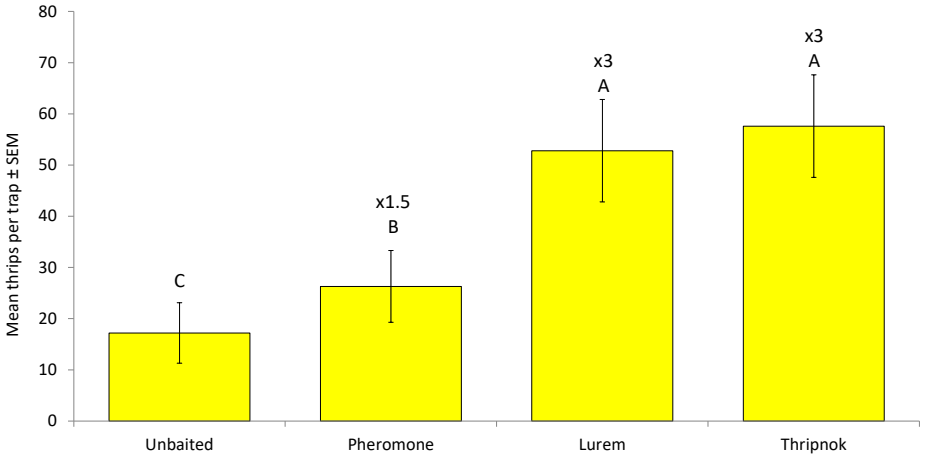

Figure 3. Mean catch ± S.E. of *F. occidentalis* on yellow sticky traps alone and with the aggregation pheromone and two kairomone lures; Lurem and Thripnok, in greenhouse strawberry showing factor of increase

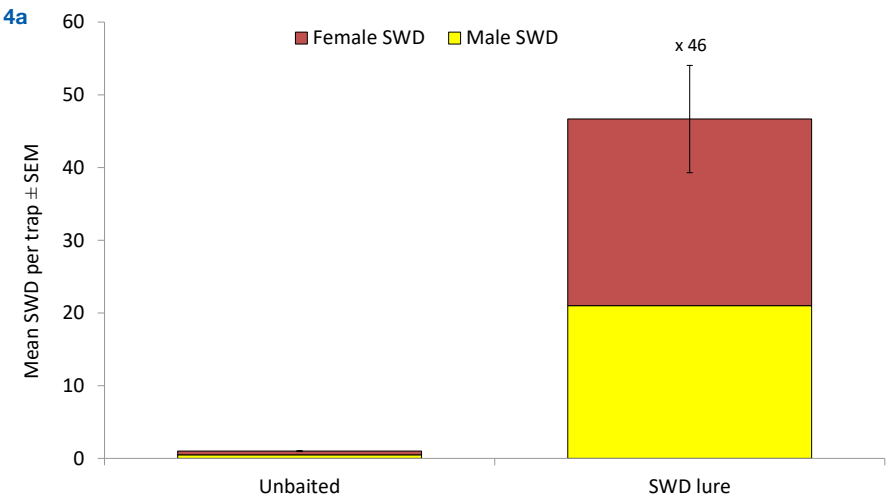

Figure 4. a) Mean catch + S.E. of *Drosophila suzukii* on red sticky traps alone and with a fruit volatile lure (SWD lure, Russell IPM) in greenhouse raspberry showing factor of increase
b) red Impact trap with SWD lure (Russell IPM). Photo: Russell IPM

vary considerably according to the weather, cultivar and market prices and predator establishment. For example, UK strawberry crops are typically at risk of economic fruit damage when adult thrips numbers exceed 4 per flower without predators, but twice as many thrips can be tolerated without fruit damage when there is a good establishment of predatory mites (Sampson and Kirk, 2016). Sticky traps from different companies also vary in colour attraction and glue type, so it is important for growers to establish monitoring records and thresholds for specific traps, crops and greenhouses. Used well, routine monitoring can be an effective tool to decide when to apply control measures, avoid unnecessary treatments, avoid pest outbreaks and crop loss and assess the impact of treatments applied, whether biological or chemical. These actions typically reduce insecticide use while maintaining or increasing crop quality, yield and profits. Published thresholds may be useful as a general guide (Table 1), but many were developed when control relied mainly on chemical insecticides, so there is a need to develop more refined thresholds, taking into account ratios of parasitoids and predators as well as pest numbers (Böckmann *et al,* 2015), now that biological control is the most important control method used in European greenhouses.

TABLE 1
EXAMPLES OF ECONOMIC INJURY THRESHOLDS USING YELLOW STICKY TRAPS

PEST OR BENEFICIAL SPECIES	TRAP TYPE AND COLOUR	ECONOMIC INJURY THRESHOLD	REFERENCE
Trialeurodes vaporariorium	Yellow sticky board Tomato 1 trap per 170m^2	<6 parasitic wasps per trap	Böckmann *et al,* 2015
Encarsia formosa			
Trialeurodes vaporariorium	Yellow sticky board Tomato, cucumber	170-250 adults per trap per week	Pinto-Zevallos and Vänninen, 2013
Frankliniella occidentalis	Yellow sticky board Pepper	20-50 thrips per day	Shipp *et al.*,2000
Frankliniella occidentalis	Yellow sticky board Ornamental crops	African Violet: <10 Impatiens: 20-30 Poinsettias: >40	Rettke, 2014

Mass trapping

The number of pests caught on attractive sticky traps is proportional to the area of trap used. When the density of sticky traps per area is increased, there reaches a point at which they catch enough pests to reduce the insect population in the crop. The density of traps required to do this will depend on the pest species and crop. Yellow sticky traps may only attract whiteflies from a relatively short distance (perhaps 50 cm?), and growers commonly use a trapping density of one trap per 2 m^2 in pest hot spots to reduce whitefly numbers.

Lu *et al.* (2012) found a significant reduction of the silver leaf whitefly, *Bemisia tabaci*, using 1 trap per 5m^2 in glasshouse aubergine, although this trap density did not achieve control in outdoor crops, where the pest pressure was greater. It has become common practice to use yellow roller traps to reduce numbers of adult whiteflies in protected crops (Figure 5a).

Where thrips are the main pest problem, the addition of blue sticky roller traps (Figure 5b) to control programmes consistently reduces numbers of adult thrips and crop damage in protected crops. 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 greenhouse strawberry, the 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 (Sampson & Kirk, 2013). In these trials, roller traps were placed down the 'legs' of each polytunnel, 8 m apart, which reduced thrips numbers throughout the tunnels. Mass trapping using sticky traps as a stand-alone treatment is rarely sufficient to maintain pest numbers below the economic damage threshold as they only catch adults, when larval stages may be more damaging. Roller traps integrate well with insecticide use as well as predator use and with bumble bee pollination. The combined use of traps and predators provides a more robust control strategy than using either method alone.

What next for sticky traps?

Sticky traps provide simple, low-tech tools that are likely to remain in widespread use. The most effective growers make excellent use of them, by collecting regular monitoring data throughout the seasons, and using these data to help make informed decisions about pest management. However, the reality is that many growers put traps up at the start of the season, use them to determine when the pests first arrive, then stop monitoring or fail to move them up as the crop grows or to replace them when they become full with pests. Mostly, this is because it is a time consuming and skilled task to count and identify all the different insect species caught on sticky traps, and growers often do not have the necessary labour available to carry out the task. Help is on hand, as many species of insect pest can now be detected and monitored automatically. Automatic detection traps have been developed for many important pests, or are in development as phone applications that will allow growers to count and identify pests on sticky traps with the click of a button (Cadim *et al,* 2020). This opens up the scope for gathering information from a wider database and for more accurate monitoring and decision making in the future. ■

Figure 5. Mass trapping of a) whitefly in cucumber using yellow roller traps (Optiroll yellow) b) thrips in strawberry using blue roller traps (Optiroll plus blue). Photos: Russell IPM

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