Pheromones and other Semiochemicals in Integrated Production and Integrated Protection of Fruit Crops
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Attraction and repulsion: the road to mirid control

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Abstract: Species of *Lygus* bugs are important pests of many crops world-wide. *Lygus rugulipennis* and *Lygocoris pabulinus* cause damage to a range of crops including strawberries and cane fruits. We have demonstrated use of the female-produced sex pheromones, attractants for the female bugs and a repellent compound to reduce damage by these pests by mass trapping and push-pull strategies that are compatible with integrated pest management programmes in horticultural crops.

Extended Summary: *Lygus rugulipennis* and *Lygocoris pabulinus* cause damage to a range of crops including strawberries and cane fruits, terminating fruiting laterals and downgrading fruit, sometimes also tainting the fruit with their odour. Recent changes to insecticide approvals have seen registration withdrawal for key mirid controlling products in the EU, including the broad-spectrum organophosphate chlorpyrifos, and more recently, the neonicotinoid, thiacloprid.

Push-pull strategies for insect pest control have commonly been based on planting around the borders and intercropping with additional plant species (Cook et al., 2007). More recently there has been interest in implementing this approach by incorporating synthetically produced compounds which can be deployed within the cropping area to repel pests from the crop and on the perimeter of the crop to attract the pest away from the crop, potentially to a lethal trap or bait.

Previous research identified the female-produced sex pheromone of *L. rugulipennis* as a blend of hexyl butyrate, (*E*)-2-hexenyl butyrate, and (*E*)-4-oxo-2-hexenal, (Innocenzi et al., 2004; 2005), and it was discovered that these three compounds needed to be released in a specific ratio to be attractive and not repellent to male *L. rugulipennis* (Fountain et al., 2014). Follow-on studies optimised the trapping system and pheromone dispenser (Fountain et al., 2010). In a small, replicated field study we further demonstrated that the addition of hexyl butyrate dispensers placed 1.0, 3.5, 5.0 and 7.0 m from traps baited with *L. rugulipennis* female sex pheromone significantly reduced male catches by 99 %, 54 %, 44 % and 20 % (Fountain et al., 2021).

In parallel, work by Groot et al. (1999) had demonstrated that *Lygocoris pabulinus* antennae responded to hexan-1-ol, heptan-1-ol, 1-octen-3-ol, 2-heptanone, (R)-carvone, linalool, geraniol, nerol, and methyl salicylate, and Frati et al. (2009) showed that *L. rugulipennis* antennae responded to methyl salicylate and (E)-β-caryophyllene. However, in the field, the most promising attractant to *L. rugulipennis* females to date had been phenylacetaldehyde (Koczor et al., 2012; Baroffio et al., 2018).

Using the combination of phenylacetaldehyde and the sex pheromone we then tested whether mass trapping (50 traps per ha) in organic strawberry crops could reduce numbers of *L. rugulipennis* and subsequent fruit damage (Fountain et al., 2015). The numbers of damaged

fruits were reduced by 4-14 % through the season but using mass traps was deemed labour intensive and not cost effective.

In replicated field trials on conventional and organic strawberry we then combined the use of the sex pheromone and phenylacetaldehyde attractants in green cross vane funnel traps around the perimeter of the crop as an attractant with hexyl butyrate inside the crop to repel *L. rugulipennis*. This resulted in reduced numbers of the pest and subsequent reduced numbers of damaged fruit by up to 90 % in organic strawberry crops (Fountain et al., 2021).

Given that hexyl butyrate, is also produced by *L. pabulinus* as part of the sex pheromone and was shown by Groot et al. (2001) to disrupt sexual communication between males and females, we then tested if we could reduce damage by *L. pabulinus* to cane fruit crops. A replicated trial was set up in a commercial raspberry. Hexyl butyrate repellent sachets significantly reduced numbers of *L. pabulinus* in the crop, and damage to fruit and young leaves by 8 %. In addition, there was no observed adverse effect on numbers of beneficials, although numbers were low.

The use of hexyl butyrate as a repellent in soft fruit crops is compatible with Integrated Pest Management and could negate the need for insecticide sprays against certain mirid pests. Currently, the repellent is formulated as a commercial product, marketed by Russell IPM (Trade name 'Lybolty').

These studies open the possibility to control mirids on a range of globally affected crops (e. g., Byers et al., 2013; Zang et al., 2015; 2021;). Future studies should focus on the use of synthetically produced semiochemicals for manipulation and control of both pest and beneficial mirid species in a range of open field and protected crops. More research is needed on how to dispense these compounds in a labour-saving way through the use automation. More evidence is needed to optimise release rates and timings through the season and diurnal releases. The ability to use several attractants and repellents in combined systems for multiple pests would also reduce costs. However, olfaction is only one of the sensory stimuli affecting insect behaviour, and there are opportunities to optimise control systems by combining with acoustic and visual components alongside IPM practices to reduce overall pest populations in and around the target crops.

Key words: capsid, economic, IPM, pests, strawberry, mass trap

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