



Efficacy of a non-pheromone semiochemical for trapping of western flower thrips in the presence of competing plant volatiles in a nectarine orchard

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Abstract

Non-pheromone semiochemicals or allelochemicals (kairomones, synomones, allomones) are often derived from, or are similar to, host plant odours and depending on their use, these semiochemicals may have to compete with the same or similar odours emanating from adjacent host plants with unknown consequences on trapping efficacy. The aim of this study was to examine the efficacy of the non-pheromone thrips attractant methyl isonicotinate (MI) as a lure for Western flower thrips (WFT; *Frankliniella occidentalis*) over a range of *Prunus persicae* nectarine plant growth stages (flowering, green fruit, ripe fruit), when competition from different host plant odours may vary, and different numbers of thrips can be present, in a Catalan nectarine orchard in 2014 and 2015. Significant 2.4–3.9 × increases in WFT numbers in traps with MI compared with those without MI were consistent over the season (flowering, green fruit, mature fruit) despite overall differences in thrips numbers on these different occasions. These results suggest that MI is an effective lure throughout the nectarine growth stages despite the presumed presence of competing and changing host plant odours. Trap type and colour and MI release rate may be important for improving overall trap efficacy.

Additional keywords: Thysanoptera; trapping efficacy; attractant; methyl isonicotinate; competing odours, *Prunus persicae*.

Abbreviations used: HGLM (hierarchical generalized linear model); MI (methyl isonicotinate); NZFT (New Zealand flower thrips); WFT (Western flower thrips).

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Competing interests: DAJT, MMD and MN all work for the New Zealand Institute for Plant and Food Research who hold the patent for methyl isonicotinate.

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Introduction

Semiochemicals (pheromone and non-pheromones) are increasingly used in insect pest management (Suckling, 2015). Non-pheromone semiochemicals or allelochemicals (kairomones, synomones, allomones) are often derived from, or are similar to, host plant odours (Koschier, 2008) and depending on their use, these semiochemicals may have to compete with the

same or similar odours emanating from adjacent host plants with unknown consequences on trapping efficacy.

Frankliniella occidentalis (Pergande), western flower thrips (WFT), is a cosmopolitan pest of many different fruit and vegetable crops (Kirk & Terry, 2003). Since its dispersal around the world in the 1980s and 1990s it has become the principal thrips pests in peach and nectarine (*Prunus persicae*) in many countries (Lacasa *et al.*, 1993; González *et al.*, 1994; Felland

et al., 1995; Pearsall, 2000; Hazir & Ulusoy, 2012; Tommasini & Ceredi, 2007; Broughton *et al.*, 2015). WFT adults are found in *P. persicae* flowers and ripe fruit (harvest) where they cause feeding damage and lay eggs (see references above). WFT management relies on insecticide applications but alternative approaches are being eagerly explored (de Kogel *et al.*, 2016) in part because of WFT's ability to develop resistance to these chemicals (Jensen, 2000). Gao *et al.* (2012) listed eight insecticide classes with different modes of action (Insecticide Resistance Action Committee codes: 1A, 1B, 2A, 2B, 3A, 4A, 5, 6) that WFT has been recorded as resistant to.

The odour of *P. persicae* flowers (Baraldi *et al.*, 1999) and fruit (Sevenants & Jennings, 1966; Do *et al.*, 1969; Spencer *et al.*, 1978; Horvat *et al.*, 1990; El-Sayed *et al.*, 2014) include volatile compounds, some of which have been identified as being attractive to WFT in laboratory and field bioassays (Koschier, 2008; Davidson *et al.*, 2008). Like other generalist thrips, WFT is considered to respond to a wide range of scents associated with flowers (Kirk, 1985). La Rue *et al.* (1972) and Teulon (1988) speculated that the characteristic odour of peach/nectarine fruit is attractive to WFT and New Zealand flower thrips (NZFT) (*Thrips obscuratus* (Crawford), respectively). Subsequently, the attraction of NZFT to several compounds found in peach fruit odour was confirmed by El-Sayed *et al.* (2014).

Methyl isonicotinate (MI) is one of several recently discovered and patented semiochemicals that has potential for a variety of uses in thrips pest management such as mass trapping, lure and kill, lure and infect, and as a behavioural synergist in conjunction with insecticides (de Kogel *et al.*, 2016; Teulon *et al.*, 2017). MI has not been identified from the odours of peach/nectarine flowers (Baraldi *et al.*, 1999) or fruit (Sevenants & Jennings, 1966; Do *et al.*, 1969; Spencer *et al.*, 1978; Horvat *et al.*, 1990; El-Sayed *et al.*, 2014) and to our knowledge not from the odours of any other flowers or fruit. MI was originally selected based on its similarity to other thrips attractants and its increased efficacy against a range of thrips species (Teulon *et al.*, 2007, 2017; Davidson *et al.*, 2008). MI is probably the most extensively studied thrips non-pheromone semiochemical, with field and glasshouse trapping experiments and wind tunnel and Y-tube olfactometer studies in several countries demonstrating a behavioural response that resulted in increased trap capture of at least 12 thrips species, including WFT (Teulon *et al.*, 2017). MI is an effective lure for flying WFT adults in nectarine orchards in Western Australia (Broughton & Harrison, 2012) and Catalonia, Spain (Teulon *et al.*, 2014a; Davidson *et al.*, 2015) but its effectiveness was

not examined throughout the growing season when there may be qualitative and quantitative changes in competing plant odours from flowers or fruit. In these previous studies the WFT numbers were very low and were aggregated for the full trapping period (Broughton & Harrison, 2012) or were carried out only at the green fruit stage (Teulon *et al.*, 2014a; Davidson *et al.*, 2015). MI needs to be shown to be active for WFT throughout the peach/nectarine growing season if it is to become a useful tool for WFT pest management.

The aim of this study was to examine the efficacy of the non-pheromone attractant MI as an attractant for WFT during nectarine flowering, green fruit and ripe fruit growth stages, when competition from different host plant odours may vary and different numbers of thrips can be present.

Material and methods

In general, methods were comparable with previous trapping of thrips with semiochemicals in Catalan nectarine orchards in 2013 as reported by Teulon *et al.* (2014a) and Davidson *et al.* (2015).

— **2014.** A single trial was conducted in a 5.6-ha 'Fantasia' nectarine orchard near Lleida (Soses) (41° 34' 53.30" N, 0° 25' 59.22" E) from 4 to 15 August 2014 to compare thrips capture on sticky traps baited with and without MI. The trial was conducted soon after fruit harvest with some intact fruit still on the orchard floor.

— **2015.** Three trials were conducted in a 2.0-ha 'Big Top' nectarine orchard near Lleida (Menàrguens) (41° 45' 0.34" N, 0° 43' 47.52" E), one each during flowering (3–10 April 2015), green fruit (7–13 May 2015) and ripe fruit (20 June–1 July 2015) to compare thrips capture on sticky traps baited with and without MI and at these different stages of nectarine fruit development.

For both years, blue sticky board traps, 10 × 35 cm (Syngenta, Almeria, Spain) were attached to a branch on the tree at a height of 1.5 m with no consistent orientation as is usual with hanging traps. Traps were 20 m apart (between both treatments and replicates), at least 30 m from the orchard edge and arranged in a 2 (treatment) × 6 (replicate) design using three adjacent Latin squares. A 4-mL glass vial was attached to each sticky board and each contained 5 × 6 cm white filter paper (Whatman no. 1) rolled into a cylinder to create a wick that protruded 1 cm above the vial opening. Each dispenser was loaded with either 1 mL of MI, which emits between 180 and 380 mg/day depending on ambient conditions (Nielsen, unpublished data), or 1 mL of water (control) as different treatments. Each trial

was repeated over time on four occasions (four trapping periods each of 2–3 days). Treatment locations were alternated for each temporal replicate and traps, vials and their contents were replaced so that there was sufficient MI throughout the trial period. Numbers of WFT and non-WFT (sexes not differentiated) caught were counted directly for each side of the sticky trap using a stereo microscope (80X magnification) and converted to daily values for better comparison between trapping periods.

All thrips were counted on all traps. In 2014, thrips were counted on two halves and on each side of all traps (*i.e.* 4 counts per trap). In 2015, thrips were counted on both sides of all traps (*i.e.* 2 counts per trap).

Differences between numbers of thrips with and without MI were compared for WFT and non-WFT thrips (species not differentiated) although few non-WFT thrips were present in 2014 (see results).

Statistical analysis

All trials were analysed similarly. Only WFT and non-WFT counts were analysed. The individual counts (four per trap in 2014 or two per trap in 2015) were analysed (*i.e.* the data were not summarized as counts per trap). Some initial analyses were carried out to assess whether there were any spatial effects (*e.g.* trends from north to south across the trial) and since there were none, no adjustments were included for such trends within the analyses.

The counts for the total trapping period (*i.e.* four trapping periods combined) for each stage of nectarine fruit development in each year were analysed for differences between traps with and without MI. The counts were analysed with either a Poisson hierarchical generalized linear model approach (HGLM, Lee *et al.* 2006) or, where there was substantial aggregation/clustering (see section 4.5 Over-dispersion in McCullagh & Nelder, 1989), with a negative binomial HGLM. This approach allows for the inclusion of random effects (such as trap location, trapping periods within a period of fruit development, trap side for 2015). Where required, the aggregation factor for the negative binomial was estimated by fitting the fixed effects (treatments with or without MI) with a Poisson distribution, and including a ‘units’ level factor (one level for each separate count) as a random effect. Logarithmic links were used for both fixed and random effects. In the results, predicted means are given along with 95% confidence limits. These were obtained on the link (log.) scale, and back-transformed. The analyses were carried out with Genstat (Payne *et al.*, 2015).

Data were further contrasted to similar bioassays comparing blue sticky traps with and without MI in a nectarine orchard near Lleida in 2013 (Davidson *et*

al., 2015). In these bioassays blue sticky traps were Horiver 10 × 25 cm (Koppert, Berkel en Rodenrijs, The Netherlands).

Results and discussion

Several thrips species are thought to inhabit Spanish peach and nectarine orchards (Riudavets & Castañé, unpublished data) but WFT is by far the most numerous and problematic (Torà *et al.*, 2010; Davidson *et al.*, 2015). This was confirmed in this study, where about 60% of thrips at flowering and close to 100% of thrips at the ripe fruit stage were WFT (Table 1).

Trial design was not optimal for comparing thrips population densities over time and between seasons, as sample intervals varied over studies. Additionally, we did not control for different nectarine varieties between years that may have influenced thrips densities. Nevertheless, relatively low thrips numbers were found at flowering compared with at harvest (Table 2), as is consistent with other studies in Spain and Italy (Lacasa *et al.*, 1993; González *et al.*, 1994; Tommasini & Burgio, 2004).

The main objective of this study was to examine differences in WFT trap capture with and without the thrips semiochemical lure MI at different stages of flower or fruit development, when there were presumably different background host plant odours. Increases in WFT numbers, including those results from Davidson *et al.* (2015) in similar Catalan nectarine orchards in 2013, of between 2.4 X – 3.9 X in traps with MI compared with those without MI were surprisingly consistent over the season (flowering, green fruit, mature fruit) despite overall differences in thrips numbers on these different occasions (Table 2) ($p < 0.001$ for all comparisons except for flowering 2015 when numbers were too low for meaningful analysis). Like any field research, the conclusions drawn from this study would benefit from additional studies carried out in different years and in different locations. However, our results show for the first time that a thrips attractant is equally effective across different stages of flower and fruit development, a condition that will be important for successful exploitation of thrips trapping technologies with attractants for thrips pest management.

Table 1. Percentage of western flower thrips (WFT) out of total thrips at different growth stages of nectarine trees.

	Flowering	Green fruit	Ripe fruit
2013 ¹	-	94.5	-
2014	-	-	98.4
2015	62.5	95.5	98.6

¹Data from Davidson *et al.* (2015).

Table 2. Mean numbers (95% confidence limits) of western flower thrips (WFT) caught on sticky traps with and without methyl isonicotinate (MI) and at different growth stages of nectarine trees. Ratios are of thrips in traps with MI to traps without MI.

	Flowering			Green fruit			Ripe fruit		
	+MI	-MI	Ratio	+MI	-MI	Ratio	+MI	-MI	Ratio
2013 ¹				160.9 (89.1,290.5)	41.0 (22.5,74.8)	3.9			
2014							56.8 (14.7,219.6)	19.9 (5.1,76.9)	2.9
2015	0.1 (0.0,0.3)	0.0 (0.0,0.2)	2.5	7.5 (3.4,16.6)	2.9 (1.3,6.3)	2.6	32.0 (20.8,49.2)	13.4 (8.7,20.5)	2.4

¹Data from Davidson *et al.* (2015).

Broughton & Harrison (2012) also found MI (in the commercial formulation Lurem-TR) to be an effective lure for WFT in nectarines but did not distinguish efficacy at different plant growth stages, and thrips numbers trapped were relatively low (< 17 thrips per trap). In Y-tube experiments, Koschier *et al.* (2017) have shown that MI remains an effective lure for WFT irrespective of background odour. Our results further demonstrate that MI is an effective lure throughout the nectarine growth stages despite the presumed presence of competing and changing host plant odours.

Trapping NZFT with another thrips lure, ethyl nicotinate, in a New Zealand stonefruit orchard showed the efficiency of this chemical throughout the growing season and that the chemical was more attractive than ripe fruit (Penman *et al.*, 1982; Teulon *et al.*, 1993). The addition of ethyl nicotinate to water traps for early-season monitoring of NZFT in a nectarine orchard significantly increased capture of adult male and female thrips (up to 27 times), and NZFT were caught in traps with ethyl nicotinate before traps without ethyl nicotinate (Teulon *et al.*, 1993). El-Sayed *et al.* (2014) used 6-pentyl-2H-pyran-2-one to increase trap captures of NZFT compared with those by unbaited traps during the harvest period in January, but there was no indication if fruit were on the trees.

Both ethyl nicotinate and 6-pentyl-2H-pyran-2-one are very strong attractants for NZFT (Penman *et*

al., 1982; Teulon *et al.*, 1993; El-Sayed *et al.*, 2014) with increased trap catches sometimes over 100 times. However, such a strong response for WFT has not been found for any chemical to date. MI has proved to be more effective than ethyl nicotinate and 6-pentyl-2H-pyran-2-one for this thrips species (Teulon *et al.*, 2014a). Increased trap catches (c. 10 X) of WFT in white water traps with MI compared with those without (Teulon *et al.*, 2014a) suggest that trap type and trap colour may be important for maximising trap efficacy. Additionally, there is growing evidence that increased odour release rates bring about increased thrips response with different thrips species/odour combinations (El-Sayed *et al.*, 2014; Teulon *et al.*, 2014b), so that increased trap capture can be brought about by manipulation of the release rate. Further research investigating factors such as trap type, trap colour and release rates is likely to be important for optimising thrips trap capture but was beyond the scope of this short communication.

The focus of this study was WFT, hence non-WFT species were not identified. Increases in non-WFT were more varied, with between 0.9 and 11.7 times as many thrips in traps with MI and traps without MI (Table 3). Differences in apparent efficacy of MI may have been due to a number of reasons, including changes in the abundance of species found at different sampling periods.

These results suggest that methyl isonicotinate is an effective lure for Western flower thrips throughout the

Table 3. Mean numbers (95% confidence limits) of non-western flower thrips species caught on sticky traps with and without methyl isonicotinate (MI) and at different growth stages of nectarine trees. Ratios are of thrips in traps with MI to traps without MI.

	Flowering			Green fruit			Ripe fruit		
	+MI	-MI	Ratio	+MI	-MI	Ratio	+MI	-MI	Ratio
2013 ¹				9.7 (4.3,21.7)	1.1 (0.4,3.3)	9.0			
2014							0.7 (0.3,1.5)	0.5 (0.2,1.1)	1.4
2015	0.1 (0.1,0.2)	0.0 (0.0,0.1)	6.5	0.4 (0.3,0.6)	0.1 (0.1,0.2)	3.3	0.3 (0.1,0.7)	0.3 (0.2,0.7)	1.0

¹Data from Davidson *et al.* (2015).

nectarine growth stages despite the presumed presence of competing and changing host plant odours.

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