MANAGEMENT OF WESTERN FLOWER THRIPS, *FRANKLINIELLA OCCIDENTALIS* (PERGANDE) (THYSANOPTERA: THRIPIDAE) ON STRAWBERRIES

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Summary

Pesticides are required to maintain effective resistance management strategies for control of western flower thrips, *Frankliniella occidentalis* (Pergande) on strawberries. Novel chemicals that may be suitable for *F. occidentalis* control in strawberries include acetamiprid, chlorfenapyr and thiamethoxam. New chemicals are required to augment the only chemical currently registered, spinosad. Rates trialled in the field included 0.5 and 1.0 g ai L^{-1} acetamiprid, 0.025 and 0.05 g ai L^{-1} chlorfenapyr, 0.3 and 0.6 g ai L^{-1} thiamethoxam and 0.01 g ai L^{-1} spinosad and were loosely based on the $LC_{99.99}$ level response of an insecticide susceptible laboratory reference strain. Insecticides were applied every three days giving a total of three successive applications as per the three spray strategy. Insecticides were applied with a Stihl® backpack mist blower, producing a total spray volume of 800 L ha^{-1}. Only acetamiprid (1.0 g ai L^{-1}) adequately controlled both adult and larval *F. occidentalis.* Application of spinosad at the lower than registered rate of 0.1 g ai L^{-1} controlled *F. occidentalis* larvae and may have a role in integrated pest management strategies that include inundative release of predatory mites.

Keywords: chemical efficacy, spinosad, acetamiprid, chlorfenapyr and thiamethoxam

INTRODUCTION

Western Flower Thrips, *Frankliniella occidentalis* (Pergande), is highly polyphagous, attacking over 240 species from 62 different plant families (Lim *et al*. 2001). Although *F. occidentalis* can damage strawberry (*Fragaria* spp.) flowers and mature fruit, most damage occurs to green fruit and fruit turning colour. Larval and adult feeding on the fruit surface causes a net-like russetting (Steiner and Goodwin 2005, Coll *et al*. 2006), reducing shelf-life and fruit appearance, which is described as “dull and rough” (Coll *et al*. 2006). On older fruit, adult and larval feeding causes russetting around the seed (achene) (Steiner and Goodwin 2005, Coll *et al*. 2006). Damage known as "cat-facing" (apical seediness and/or seediness on the rest of the fruit) has been attributed to *F. occidentalis* and other thrips species, and to Rutherglen bug (*Nysius vinitor* Bergroth) (Houlding 1997). Damage to strawberry flowers is regarded as commonly occurring only when thrips populations are very high (Steiner and Goodwin 2005), and is characterised by brown and withered stigma and anthers, and slight necrotic spots on the calyx of the flower (Steiner and Goodwin 2005, Coll *et al*. 2006).

To prevent economic loss from *F. occidentalis* many commercial strawberry growers rely on chemical control. Since *F. occidentalis* develops resistance to insecticides (reviewed by Jensen 2000), an insecticide resistance management strategy (IRMS) was introduced for a range of commercial crops shortly after *F. occidentalis* was first detected in Australia (Gollnow *et al.* 1993). This strategy recommends the alternation or rotation of insecticides from different chemical groups (classes), which are classified according to mode of action (IRAC 2007). Briefly, the strategy requires the use of one chemical class for a series of three consecutive sprays, three to six days apart, dependent on temperature, then switching to another chemical group for the next series of three sprays (Broughton and Herron 2007). Similar strategies are being used for *F. occidentalis* control in the United States of America (USA) (Robb *et al*. 1995) and Spain (IRAC 2008). However, since some growers repeatedly spray the same insecticide, without rotation, and often without pest monitoring, resistance to registered insecticides has developed. Resistance to newer chemistry insecticides has already been reported for fipronil (Regent®), in lettuce eight years after it was registered in Australia (Herron and James 2005), and for spinosad (Success®), three years after it was introduced (Herron and James 2005). Some older products containing carbamate or organophosphate insecticides are also likely to be deleted through the Australian pesticide registration review process (APVMA 2007 a, b) leaving growers with fewer chemical options.

We recognised the need to identify and trial new chemicals to ensure growers continued access to effective insecticides. Three potential new insecticides for use in strawberry against *F. occidentalis* include acetamiprid, chlorfenapyr, and thiamethoxam. All are considered ‘reduced risk’ insecticides, because of their narrow spectrum of activity. This makes them potentially less harmful to beneficial insects than older broad spectrum organophosphate, carbamate and pyrethroid insecticides (Villanueva and Walgenbach 2005). Here we use laboratory bioassay results and report field efficacy data for acetamiprid, chlorfenapyr and thiamethoxam against *F. occidentalis* plus a lower than registered rate of spinosad that may be compatible with integrated pest management (IPM) programs.

MATERIALS AND METHODS

To determine logical application rates for the field trial, laboratory bioassays (Herron *et al.* 1996) were conducted against a reference susceptible strain of *F. occidentalis* (Herron and Gullick 1998) using the products listed in Table 1. Probit regressions including control correction (Abbott 1925) were calculated using a purpose written program (Barchia 2001) and the $LC_{99.99}$ level response and its 95% fiducial limits calculated.

A field trial was carried out on a commercial strawberry property in Bullsbrook (S 31°39.294’, E 115º58.589), 54 km north of Perth in December 2005. Strawberries (cv. Majestic) were grown on raised beds of sand covered with black polythene sheet and irrigated by overhead irrigation and drip (T-tape) irrigation. The experimental design was a randomised complete block comprising eight treatments and four replicates. Each block contained all treatments, with an individual replicate consisting of approximately 100 plants in an 80 m x 0.75 m plot. There was a 0.6 m wide untreated buffer strip between replicates.

Pre- and post-treatment thrips counts were used to estimate the effectiveness of each treatment. Twenty full, open flowers of a consistent age were randomly selected from each replicate before the first spray application (pre-treatment) and three days after the last of the three consecutive insecticide applications and placed directly into 700 g L^{-1} ethanol. In the laboratory, the numbers of thrips extracted from the flowers and alcohol were recorded. Adult thrips were identified to species using the taxonomic criteria of Moritz *et al.* (2001). Pre-spray counts were examined using a covariance analysis with a randomized complete block design. Post-treatment adult and larvae counts were then fitted to a generalized linear mixed effect model, with the link function being log (count) = random (block) + fixed (treatment). The errors were assumed to follow a Poisson distribution. Treatments were compared using the least significant difference test at the 5% significance level. All analyses were run on ASReml Release 2.00 (Gilmour *et al.* 2006).

Application rates of acetamiprid, chlorfenapyr and thiamethoxam trialled included a concentration loosely based on the $LC_{99.99}$ (±95% fiducial limits (FL)) estimate, and double that concentration. A single application rate of spinosad was tested (Table 2). Treatments were applied every three days, giving a total of three successive applications as per the published three spray strategy (Broughton and Herron 2007). Insecticides were applied with a Stihl® backpack mist blower (model SR 420) with a 1.5 m hand-held boom fitted with 30° round, hollow-cone nozzles producing a total spray volume of 800 L ha^{-1}. Control plots were sprayed with water only.

RESULTS

Results of the laboratory bioassays indicated $LC_{99.99}$ estimates of 0.39 (0.24-0.78) g ai L^{-1} for acetamiprid, 0.037 (0.014-0.54) g ai L^{-1} for chlorfenapyr, 0.22 (0.14-0.46) g ai L^{-1} for thiamethoxam and 0.0073 (0.0054-0.011) g ai L^{-1} for spinosad.

Pre-spray counts of *F. occidentalis* adults and larvae were not significantly different between blocks. *F. occidentalis* accounted for 96% of the total thrips population during the trial. Of all insecticides tested only acetamiprid at 1.0 g ai L^{-1} was effective at significantly reducing adult numbers with an overall efficacy of 53% (Table 2). Both rates of chlorfenapyr and thiamethoxam were ineffective at reducing adult thrips numbers, as was the spinosad treatment.

With the exception of chlorfenapyr, all insecticides were more effective against thrips larvae than adults. Both application rates of chlorfenapyr failed to control larvae, with efficacy less than 11% (Table 2). Larval mortalities following application of either rate of acetamiprid or thiamethoxam or the single rate of spinosad were significantly different from that in the

Table 1. Common name, trade name, formulation and supplier of the insecticides tested.

Common name	Trade name	Formulation[1]	Supplier
Spinosad	Success™ Naturalyte™	120 g L^{-1} EC	Dow AgroSciences Aust Ltd
Acetamiprid	Mospolan™	225 g L^{-1} SL	Dupont (Australia) Ltd
Chlorfenapyr	Secure®	360 g L^{-1} SC	BASF Australia Ltd
Thiamethoxam	Meridian®	250 g kg^{-1} WG	Syngenta Crop Protection

[1]EC = emulsifiable concentrate; SL = soluble concentrate; SC = suspension concentrate; WG = water dispersible granule

Table 2. Mean numbers (transformed data) of adult and larval *Frankliniella occidentalis* and percentage efficacy to a range of insecticides in strawberry.

Treatments		Adults		Larvae	
	Field application rate (g ai L^{-1})	Geometric mean*	Efficacy (%)	Geometric mean*	Efficacy (%)
Control	N/A	153.7ab	-	191.8a	-
Spinosad	0.01	131.5ab	14.45	27.3e	85.79
Acetamiprid	0.5	104.6bc	31.94	36.0de	81.23
Acetamiprid	1.0	72.0c	53.13	27.0e	85.92
Chlorfenapyr	0.025	162.3a	0	172.3a	10.17
Chlorfenapyr	0.05	152.4ab	0.80	177.8a	7.30
Thiamethoxam	0.3	113.7ab	26.00	89.0bc	53.59
Thiamethoxam	0.6	111.3ab	27.61	55.8cd	70.93

* Within columns, values followed by the same letter do not significantly differ at $P = 0.05$.

controls (Table 2).

DISCUSSION

Strawberry growers currently have access to two classes of insecticides to control *F. occidentalis*, the spinosyns (registered) and avermectins (available under permit). Each class is represented by a single insecticide only. Consequently, growers are currently limited in their ability to follow the IRMS based on chemical alternation or rotation (Herron and Cook 2002), particularly since product labels prohibit more that two applications of avermectins per season. Our study has shown that 1.0 g ai L^{-1} acetamiprid adequately controlled both adult and larval *F. occidentalis* whilst 0.06 g ai L^{-1} thiamethoxam significantly reduced larval numbers only. Both insecticides have contact, translaminar and systemic activity, whist thiamethoxam has systemic and long residual activity in several plants (McLeod *et al*. 2002). The result for thiamethoxam seems inconsistent with overseas registrations where both thiamethoxam and acetamiprid are used for the control of sucking and chewing insect pests in a range of crops. It should be noted that field application rates in this study were loosely based on $LC_{99.99}$ estimates for a reference susceptible strain and yet, mortalities in the field fell short of this level of control. The discrepancy between field and bioassay data may be explained by the different methods of application. Although thorough, the insecticide deposits from the backpack mist blower may have been less uniform, of different droplet size or lower than those achieved in the laboratory bioassays. Moreover, although not expected in the targeted field population, the possibility that the thrips were cross resistant to these new insecticides cannot be entirely discounted. In the USA, registrations for acetamiprid and thiamethoxam were granted in 2002 (Ware and Whitacre 2004) with registrations for use against thrips in *Brassica*, cucurbits, fruiting vegetables and cotton. Acetamiprid is registered for use against thrips in cole, fruiting vegetables and cotton (EPA 2002). Chlorfenapyr is a pro-insecticide that requires activation by the insect's own metabolism to create an active molecule that interferes with oxidative phosphorylation (Hunt and Treacy 1998). Chlorfenapyr applied at 0.05 g ai L^{-1} had no significant effect against adult or larval *F. occidentalis* in the field trial. Our results agree with those of Seaton *et al*. (1997), where chlorfenapyr applied at the higher rate of 0.67 g product L^{-1} (approximately 0.24 g ai L^{-1} for the commercial 360 suspension concentrate formulation), reduced adult *F. occidentalis* numbers by only 13.7% after three consecutive sprays.

Beneficial organisms that attack *F. occidentalis* have recently also become available to Australian growers (ABC 2009). These include the predatory mites *Typhlodromips montdorensis* (Schicha) and *Neoseiulus cucumeris* (Oudemans) (Acari: Phytoseiidae), which feed on thrips larvae, and *Stratiolaelaps* (*Hypoaspis*) *nr miles* (Berlese) (Acari: Laelapidae), which feed on pupae (Llewellyn 2002). A native predatory bug, *Orius armatus* Gross (Heteroptera: Anthocoridae) that attacks thrips larvae and adults (Cook *et al.* 1996) is also being reared, although it is not yet commercially available. Preliminary field trials in low tunnel (cloches) strawberry crops (T. Rahmann pers. comm) have shown that

F. occidentalis can be suppressed by applying spinosad, then releasing single, or multiple species combinations of predatory mites. For this reason the low 0.01 g ai L^{-1} rate of spinosad trialled here may be compatible with biological control of *F. occidentalis*. The ability to use spinosad at reduced rates in association with beneficial organisms is critical because recent data on the side-effects of acetamiprid and thiamethoxam suggest that both are more toxic to beneficial arthropods than spinosad (Poletti *et al*. 2007, Biobest 2009). Toxicity of acetamiprid to *N. cucumeris* and *S.* nr *miles* is slight to moderate but is high to the predatory mite *Phytoseiulus persimilis* (Athias Henriot) (Acari: Phytoseiidae), whilst thiamethoxam is moderately toxic to *S.* nr *miles* and highly toxic to *P. persimilis* (Biobest 2009). The results of various researchers work on the effects of insecticides on beneficial organisms is summarised in Biobest (2009). They consider that growers may need to wait five to seven days after applying acetamiprid or thiamethoxam, before releasing predatory arthropods in an integrated control system for *F. occidentalis* in strawberry.

Although some new insecticides may improve control of *F. occidentalis,* analysis of strawberry grower spray diary records in 2008 indicated that some growers were not following an IRMS strategy. For example, during a four week interval one commercial grower had sprayed seven times with methomyl and once with spinosad to control thrips and five times with abamectin to control two-spotted spider mite, *Tetranychus urticae* Koch (S. Broughton unpubl. data). Furthermore, it became clear that some growers require training to identify *F. occidentalis* since they were using methomyl to verify whether *F. occidentalis* were present in their crop. Methomyl is efficacious against thrips such as *Thrips imaginis* Bagnall, which also occur in strawberry (Houlding 1997), but *F. occidentalis* has some resistance to this insecticide (Herron and James 2005). If methomyl is sprayed and thrips remain, growers conclude that *F. occidentalis* was present. However, recent improvements have occurred within the strawberry industry that should extend the life of currently registered and new insecticides. This has occurred, in part, as a response by the strawberry industry to chemical control failures against *F. occidentalis*. Termed 'big bang' implementation, insecticide resistance provides a powerful impetus for change (Norton 1982). Improvements include a thrips identification course for growers, crop scouting and innundative release of the predatory mite, *P. persimilis* for the control of *T. urticae* (L. Chilman pers. comm).

ACKNOWLEDGMENTS

Idris Barchia is thanked for the statistical analysis and Louise Rossiter for critical comment on an early draft. David Cousins and Tanya Tomlinson provided technical assistance. The project was facilitated by HAL in partnership with ASVEG, Australian Processing Tomato Research Council and Strawberries Australia Inc. and was funded by the vegetable, processing tomato and strawberry levy. The Australian Government provides matched funding for all HAL's R&D activities.

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