INSECTICIDE RESISTANCE IN AUSTRALIAN POPULATIONS OF *FRANKLINIELLA OCCIDENTALIS* (PERGANDE) (THYSANOPTERA:THRIPIDAE) CAUSES THE ABANDONMENT OF PYRETHROID CHEMICALS FOR ITS CONTROL

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Summary

High-level insecticide resistance in western flower thrips (WFT) has the potential to compromise their resistance management. We aimed to identify such resistance and eliminate it from the chemical control strategy based on the alternation of chemical groups. Abamectin, endosulfan or methidathion resistance was not detected and those chemicals can be used with confidence against WFT. In contrast, high-level pyrethroid (αcypermethrin, bifenthrin, deltamethrin and τfluvalinate) resistance was detected in all populations tested. Pyrethroids are no longer recommended for use against Australian WFT. Low-level malathion, chlorpyrifos, methomyl and methiocarb resistance was detected and meticulous monitoring is required to identify any change in their status. Some strains were resistant to carbamates, pyrethroids and organophosphates and so may be multiple resistant.

Key words: western flower thrips, resistance management

INTRODUCTION

Western flower thrips (WFT) was first detected in Western Australia in 1993 (Malipatil *et al.* 1993). Except for the Northern Territory, WFT is now established throughout Australia (Medhurst and Swanson 1999). WFT continues a relentless push into areas that were once free and invariably causes severe crop losses (Medhurst and Swanson 1999). The mainstay control of WFT in Australia relies on a limited number of pesticides predominantly made available under permit from the National Registration Authority.

Overseas experience indicated that insecticide resistance could be a serious threat to effective WFT control (Brødsgaard 1994, Helyer and Brobyn 1992). Although resistance had not been confirmed at that time, a resistance management strategy based on chemical alternation was introduced soon after the discovery of WFT in Australia. Briefly, the recommendation was three consecutive sprays of the same insecticide 3-6 days apart (dependant on ambient temperature) followed, if necessary, at least 2 weeks later, with an other series of 3 sprays using chemicals from a different group.

A recent Australian study detected high (114 x LC50 and 800x at LC99) αcypermethrin resistance (Herron and Cook, unpub. data) and demonstrated that resistance factors had increased whether growers used the current resistance management strategy or not. It was shown that resistance did not revert despite chemical alternation. This undermined the management of those chemicals to which there was no resistance. It became clear that alternation with ineffective chemistry was equivalent to not alternating at all.

The aim of this study was to measure the resistance to the chemicals used for WFT control with a view to eliminating ineffective insecticides from the Australian WFT control strategy.

MATERIALS AND METHODS

Pesticides

Insecticide common name, proprietary name, concentration, formulation and supplier are given in Table 1. It was not possible to test all insecticides against all strains (Table 2).

Thrips

The collection history and base-line responses of the susceptible strain (NZ2) has been given previously in Herron and Gullick (1998). Field-collected WFT were sourced from every Australian State (Table 2), placed in ventilated, thrips-proof containers, and forwarded by overnight courier to the laboratory in NSW. Except for the Tasmanian populations, field-collected WFT came from commercially sprayed and managed crops. The Tasmanian strains were collected in early spring, being over-wintering remnants from an earlier infestation.

Table 1. Common name, proprietary name, concentration, formulation and supplier of chemicals tested for resistance against Australian field-collected strains of western flower thrips.

Chemical	Product	Concentration and formulation	Supplier
abamectin	Avid®	18 g L^{-1} emulsifiable concentrate (EC)	Novartis Crop protection Australasia Limited, Pendle Hill
acephate	Orthene® Insecticide	750 k kg^{-1} water dispersible granule(WG)	Aventis CropScience Pty Ltd, East Hawthorn
α cypermethrin	Fastac® 100 Insecticide	100 g L^{-1} EC	Cyanamid Agriculture Pty. Limited, Baulkham Hills
bifenthrin	Talstar® 100 EC Insecticide	100 g L^{-1} EC	Crop Care Australasia Pt Ltd, Pinkenba
chlorpyrifos	Lorsban® 500 EC Insecticide	500 g L^{-1} EC	Dow AgroSciences Australia Ltd, Frenches Forest
deltamethrin	Decis Forte® EC Insecticide	27.5 g L^{-1} EC	Aventis CropScience Pty Ltd, East Hawthorn
dichlorvos	Vapona 500	500 g L^{-1} EC	Cyanamid Agriculture Pty. Limited, Baulkham Hills
endosulfan	Crop King Endosulfan 350 EC Insecticide	350 g L^{-1} EC	Crop care Australasia Pty Ltd, Pinkenba
fipronil	Regent 200 SC Insecticide	200 g L^{-1} suspension concentrate (SC)	Aventis CropScience Pty Ltd, East Hawthorn
malathion	Maldison 500 Insecticide	500 g L^{-1} EC	Aventis CropScience Pty Ltd, East Hawthorn
methamidophos	Nitofol® Insecticide Spray	580 g L^{-1} EC	Bayer Australia Limited, Pymble
methidathion	Supracide 400 EC Insecticide	400 g L^{-1} EC	Novartis Crop protection Australasia Limited, Pendle Hill
methiocarb	Measurol 750 Bird Repellent and Snail and Slug spray	750 g Kg^{-1} wettable powder (WP)	Bayer Australia Limited, Pymble
methomyl	Lannate™ LV Insecticide	225 g L^{-1} soluble concentrate (SL)	Crop Care Australasia Pty Ltd, Pinkenba
pyrazophos	Afugan® Fungicide	295 g L^{-1} EC	Aventis CropScience Pty Ltd, East Hawthorn
ι fluvalinate	Mavrik® Aquaflow Insecticide	7.5 g L^{-1} aqueous concentrate (AC)	Novartis Crop protection Australasia Limited, Pendle Hill

Culturing

Thrips were cultured on potted dwarf French bean (*Phaseolus vulgaris* L.) using methods given in Herron and Gullick (1998). Briefly, the WFT were reared in purpose built rearing cages on potted bean plants with Cumbungi (*Typha domingensis* Pers.) pollen and honey as a supplementary food source. Thrips were transferred onto fresh plants in a new cage on a six-weekly-cycle and maintained at 25±1°C under an 18:6 hour L: D regime.

Bioassay

The bioassay procedure is given in Herron *et al.* (1996). Briefly about 120 (N=30/conc.), lightly CO_2 anaesthetised WFT were tipped onto French bean-leaf discs embedded in agar in small Petri dishes. The leaf discs with thrips in place, were then sprayed (deposit of 3.2 mg cm^{-2}) using a Potter spray tower with a 4 mL aliquot of serially diluted insecticide or with water (control). The concentration series included the susceptible discriminating-concentration (dose) which had been determined previously against a laboratory susceptible strain (Herron and Gullick 1998). The Petri dish was covered with taut plastic cling-wrap film perforated with 40-50 fine holes. The dishes were stored for 48 h at 25±0.1 °C after which the numbers of alive and dead thrips were counted. Each test was replicated once.

Statistical analysis

Mortality at the discriminating-dose was corrected for control mortality (Abbott 1925) however this never exceeded 15%. LC50 and LC99.9 values were calculated using the probit method outlined in Finney (1971). Resistance factors were calculated by dividing the LC50 (or LC99.9) for the field strain by that for the laboratory susceptible strain.

RESULTS

Abamectin, endosulfan and methidathion resistance

Table 2. The presence (✔) or absence (✘) of resistance (as indicated by survivors at the discriminating dose*) in each strain of western flower thrips tested.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
NSW	✘	NT	✘	✘	✘	✔	✔	NT	✘	✔	✘	✘	NT	✔	✔	NT
Qld	✘	✔	✔	✘	✔	✘	✔	✘	✔	✘	✘	✘	✔	✔	✔	✔
SA	✘	✔	✘	✘	✘	✘	✔	✘	✔	✘	✘	✔	✔	✔	✔	✔
Tas-A	✘	✘	✘	✘	✘	✘	✔	✘	✔	✘	✘	✘	✔	✔	✔	✔
Tas-B	✘	NT	NT	✘	✘	✘	✔	NT	NT	NT	NT	NT	✔	✔	NT	NT
Vic	✘	✔	✔	✘	✘	✘	✔	✘	✔	✘	✘	✘	✔	✔	✔	✔
WA	✘	✘	✘	✘	✘	✘	✔	✔	✘	✔	✘	✘	✔	✔	✔	✔

1. INSECTICIDE (CLASS)

A. Abamectin (avermectin)
B. Methiocarb (carbamate)
C. Methomyl (carbamate)
D. Endosulfan (cyclodiene)
E. Fipronil (fiprole)
F. Acephate (organophosphate)
G. Chlorpyrifos (organophosphate)
H. Dichlorvos (organophosphate)
I. Malathion (organophosphate)
J. Methamidiphos (organophosphate)
K. Methidathion (organophosphate)
L. Pyrazophos (organophosphate)
M. αcypermethrin (pyrethroid)
N. Bifenthrin (pyrethroid)
O. Deltamethrin (pyrethroid)
P. τFluvalinate (pyrethroid)

NT = not tested.
* = 0.3 g abamectin L^{-1}, 5.0 g acephate L^{-1}, 0.01 g α cypermethrin L^{-1}, 0.05 g bifenthrin L^{-1}, 0.1 g chlorpyrifos L^{-1}, 0.06 g deltamethrin L^{-1}, 0.6 g dichlorvos L^{-1}, 1.5 g endosulfan L^{-1}, 0.08 g fipronil L^{-1}, 0.3 g malathion L^{-1}, 0.4 g methamidophos L^{-1}, 1.0 g methidathion L^{-1}, 0.2 g methiocarb L^{-1}, 0.3 g methomyl L^{-1}, 1.0 g pyrazophos L^{-1} or 0.2 g τ fluvalinate L^{-1}

was not detected (Table 3). One or two strains contained a small proportion of survivors at the susceptible discriminating-dose of acephate (3%), dichlorvos (5%), pyrazophos (4%), fipronil (7%), and methamidophos (3%) and not surprisingly resistance levels were low (<4.4x at LC50). All strains tested were resistant to a cypermethrin (9.3 – 41x at LC50) with one strain comprising only resistant WFT. Similarly, bifenthrin, deltamethrin and τfluvalinate resistance was detected in all strains (8.1 – 29, 10 – 100 and 39 – 89x respectively at LC50). Chlorpyrifos and malathion resistance was common although resistance levels were low (1.8 – 6.1 and 1.0 – 2.9x respectively at LC50). However, results at the LC99.9 suggest a small proportion of highly chlorpyrifos and malathion resistant individuals in one strain (SA). Methiocarb and methomyl resistance was detected in about half the strains tested and again LC50 level resistance was generally low (<6.4x). LC99.9 level results indicated the presence of highly methiocarb and methomyl resistant individuals in one strain (Vic). Strains Qld, SA and Vic were carbamate, organophosphate and pyrethroid resistant and so may be multiple resistant (Table 2).

DISCUSSION

The results of our field survey underpin the recommended WFT resistance management strategy. Abamectin, endosulfan and methidathion can be recommended in confidence, in the knowledge that Australian WFT remain susceptible to each. It is also likely that acephate, dichlorvos, methamidophos, pyrazophos and fipronil remain fully effective. Although some populations contained a small percentage of survivors at a concentration lethal to the susceptible strain, resistance factors were very low. This does not necessarily indicate resistance and in the case of fipronil, resistance factors remained unchanged despite laboratory selection with fipronil (Herron and Gullick, unpubl. data). For these insecticides, it is more likely that the susceptible discriminating-dose set at the LC99.9 level of the laboratory susceptible strain (Herron and Gullick 1998) may not be as robust as first thought. It may not clearly delineate vigour tolerance from incipient resistance.

Susceptibility, both within and between populations is normally distributed (Busvine 1971). However, our susceptible discriminating-doses were determined against a single imported susceptible strain. Where in the normal response range describing susceptibility this strain falls, is unknown, and without further insecticide-naive populations will remain unknown. In hindsight, it may have been wiser to "build in" a factor to accommodate this unknown variation. It may have been more appropriate to use the LC99.99 level for the reference susceptible strain or perhaps 2x the minimum-effective-dose for the susceptible.

The situation with the other insecticides was clearer. Pyrethroid resistance, usually at high level (>40x at LC50) was detected in every WFT strain tested. Lack of efficacy is putting increased pressure on the insecticides to which resistance has not developed. Consequently, we consider that pyrethroids should no longer be recommended against Australian WFT.

Malathion and chlorpyrifos resistance was also detected in all strains. However, LC50 resistance factors were low (<6.1x) but LC99.9 data make us suspect that some populations contain a small proportion of highly resistant individuals. Under intense spray pressure resistant WFT have enormous potential to increase in number, with a coincidental rise in resistance factor (Herron and Cook unpubl. data). For this reason, malathion and chlorpyrifos resistance should be monitored and their strategic use reviewed as new data are collected. Similarly, results for methomyl and methiocarb suggest that carbamate resistance is currently at manageable frequencies but requires ongoing monitoring and review.

WFT resistance management in Australia is at a critical stage. Although a number of compounds remain effective, pyrethroids are, for all intents and purposes, lost. Unless well managed the future for organophosphate and carbamate compounds is also under threat. Populations from Qld, SA and Vic were carbamate, organophosphate and pyrethroid resistant. This suggests that multiple resistance mechanisms may be involved. Multiple resistant WFT have already been found in both the USA (Zhao *et al.* 1994) and Denmark (Jensen 1998). In order to preserve WFT susceptibility to compounds like fipronil it is essential that the newer chemistries are not overused in the revised resistance management strategy. Failure to manage these compounds effectively could mean they too could succumb under the intense selection pressure exerted under commercial horticultural production systems.

ACKNOWLEDGMENTS

HRDC is acknowledged for funding. Tanya James and Ross Parkes provided technical assistance. All the persons who forwarded strains for testing are thanked.

Table 3. Discriminating-dose and resistance factors against field-collected strains of *Frankiniella occidentalis* tested for resistance.

Chemical class	Chemical	Range: % surviving DD*	RF# range: LC50 level	RF# range: LC99.9 level
avermectin	abamectin	NA	NA	NA
carbamates	methiocarb	17 - 34	3.6 - 6.4x	22 - 3,610x
	methomyl	4 - 52	2.3 - 4.5x	1.9 - 65x
cyclodiene	endosulfan	NA	NA	NA
fiprole	fipronil	7	2.0x	5.0x
organophosphates	acephate	3	4.4x	4.1x
	chlorpyrifos	3 - 63	1.8 - 6.1x	1.9 - 273x
	dichlorvos	5	1.4x	3.7x
	malathion	23 - 40	1.0 - 2.9x	6.4 - 33x
	methamidophos	3 - 3	1.6 - 2.5x	2.0 - 3.3x
	methidathion	NA	NA	NA
	pyrazophos	4	1.5x	2.8x
pyrethroids	αcypermethrin	58 - 100	9.3 - 41x	32 - 915x
	bifenthrin	19 - 90	8.1 - 29x	13 - 10,819x
	deltamethrin	5 - 78	10 - 100x	4.0 - 708x
	τfluvalinate	55 - 89	30 - 89x	145 - 99,875x

* % sur. DD = Percent surviving a discriminating dose (see foot note Table 2)
\# RF = Resistance Factor: LC50 or LC99.9 field strain / LC50 or LC99.9 laboratory susceptible strain
NA = not applicable, all strains susceptible

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