SUSCEPTIBILITY OF *SCAPTOMYZA FLAVA* (DIPTERA: DROSOPHILIDAE) TO INSECTICIDES

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ABSTRACT

The leaf miner, *Scaptomyza flava* (Diptera: Drosophilidae), can damage Asian brassicas. Methods of control are required that are compatible with biological control of the lepidopteran pests that also damage this crop. Laboratory bioassays compared the susceptibility of adult flies and first instar larvae in leaf mines to 12 insecticides registered for use on brassicas and the insecticide abamectin. The efficacy of seven insecticides were compared in two field trials with Joi Choi and Pak Choi, and the survival of a larval/pupal parasitoid, *Asobara persimilis* (Hymenoptera: Braconidae) was assessed. Adult and larval flies were susceptible to nine insecticides. In the field trials, abamectin, deltamethrin, endosulfan and fipronil gave good control of fly larvae. Parasitoids emerged in treatments where fly larvae survived to pupate, i.e. abamectin, endosulfan, maldison, spinosad and indoxacarb.

Keywords: leaf miner, parasitoid, field trials, insecticide bioassays.

INTRODUCTION

The leaf miner, *Scaptomyza flava* (Fallen 1823) (Diptera: Drosophilidae), was first detected in New Zealand in 1964 (Martin 2004). This polyphagous species has been recorded from 10 families of plants (Maca 1972; Martin 2004; N.A. Martin, unpubl. data), but is principally found on Brassicaceae and is regarded as a pest on some brassica crops, peas (*Pisum sativum* L. (Fabaceae)) and gypsophila (*Gypsophila* sp. (Caryophylaceae)). The leaf miner is rarely a problem on European vegetable brassicas, such as cabbage, broccoli and cauliflower, but is readily found in unsprayed Asian brassicas, such as Chinese cabbage (*Brassica campestris* spp. *pekinensis*), and Joi Choi, Pak Choi and Choi Sum.

Integrated pest management has been developed in New Zealand for use in European vegetable brassicas crops (Berry 2000). In order to extend this to Asian brassicas, methods for control of the leaf mining fly are required that are compatible with insecticide resistance prevention and management strategies for diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Gelechidae) and green peach aphid, *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), and that are not harmful to the parasitoids of diamond back moth. This paper reports on laboratory experiments to assess the susceptibility of adults and larvae to insecticides registered for use on brassicas and to an insecticide, abamectin, used for leaf miner control overseas, e.g. USA (Trumble 1985). In addition, results from two field trials in which the effect of foliar applications of seven insecticides on plant damage, larval fly numbers and the proportion parasitised by the larval/pupal parasitoid, *Asobara persimilis* (Papp) (Hymenoptera: Braconidae) are presented.

METHODS

Laboratory insecticide bioassays

For adult flies, discs 50 mm in diameter were cut from leaves from small Asian brassica plants cv. Riko. After dipping for 5 s either in water or an insecticide solution (Table 1), the dried leaf discs were placed on white filter paper (42.5 mm diameter) in Petri dishes (50 mm diameter, 9 mm high). Adult flies were anaesthetised with carbon dioxide to facilitate handling and 10 females were added to each dish. The dishes were kept at 20°C and fly mortality recorded after 24 and 48 h. There were five dishes per treatment and from one to five insecticides and a water control were tested at any one time. Each insecticide was tested at least twice (Table 2).

For fly larvae, pots with four small plants, cv. Riko, were placed in a cage with 50 adult (male and female) flies for 24 h. The plants were kept in a heated greenhouse for 5-7 days until narrow mines formed by first instar larvae were observed. Infested leaves were detached and an estimate made of the number of mines present in each leaf. Each leaf was dipped for 5 s either in water or an insecticide solution (Table 1), and left to stand in a container of water in a room at 20°C. After 2-3 days the leaf was put in a plastic container (700 ml) containing tissue paper and, if the leaf was heavily infested, an uninfested, untreated leaf into which larvae could transfer to complete their development. The number of puparia that developed was recorded after a further 10 days. In each experiment there were four replicates of each treatment and some insecticides were tested more than once (Table 2).

TABLE 1: Insecticides, concentration used in bioassays with adult female and juvenile *Scaptomyza flava* and rates used in field trials.

Common name	Product	Chemical group (and class no.)	Concentration (g ai/litre)[1]
abamectin[2]	Agrimec	Avermectin (6a)	0.009
acephate	Orthene WSG	Organophosphate (1b)	0.776
Bt aizawai	Xentari	*Bacillus thuringensis* aizawai (11b1)	–
carbaryl	Carbaryl 50 F	Carbamate (1a)	1.2
deltamethrin	Decis Forte	Pyrethroid (3)	0.01
endosulfan	Thiodan 35 EC	Cyclodiene organochlorine (2a)	0.7
fipronil	Ascend	Phenyl pyrazole (2b)	0.048
indoxacarb	Steward 150 SC	Indoxacarb (22)	0.15
maldison	No Insects Maldison	Organophosphate (1b)	1.5
methamidophos	Tameron	Organophosphate (1b)	1.8
pirimicarb	Pirimor	Carbamate (1a)	0.25
pymetrozine	Chess WG	Pymetrozine (9b)	0.2
spinosad	Success Naturalyte	Spinosyns (5)	0.096

[1]Insecticide concentration is based on recommended field rates for vegetable brassicas as product/100 litres or, if product/ha, in 500 litres water/ha.
[2]Abamectin is not registered in New Zealand for use on brassicas but is used overseas for leaf mining fly control.

Field trials

For field trials, Asian brassicas were direct-sown into beds 1.8 m wide and 60 m long at Pukekohe Research Centre, South Auckland. In trial 1, three beds, one each of Joi Choi, Pak Choi Sumo and Choi Sum Evergreen, were sown on 17 November 2005. There were four rows of plants per bed. In trial 2, one bed with Joi Choi and one of Pak Choi Sumo were sown on 18 January 2006 with three rows per bed. In all cases plots were 3 m long and the width of the bed. Four insecticide treatments (Trial 1–Table 3;

Trial 2–Table 4) and untreated control were replicated four times and arranged in randomised block designs.

Insecticides were applied at recommended rates (Table 1) in 500 litres/ha by a knapsack sprayer with three TeeJet XR8004VS nozzles. Insecticides were applied three times in both trials, on 23 December 2005, 3 and 13 January 2006 for trial 1 and on 16 February, 2 and 16 March 2006 for trial 2.

The Asian brassica cultivars matured at different times after sowing. In trial 1, a preliminary assessment to work out sampling methods was made of Joi Choi on 11 January and a full assessment of Pak Choi on 18 January. In the latter, three plants per plot were removed from the central rows and the total number of leaves and those with leaf mines recorded. Leaves with mines were taken to the laboratory in plastic bags and next day placed on absorbent paper in 1-litre or 2-litre ice-cream containers, enclosed in a plastic bag and kept at 20°C for 4 days. Puparia from each container were placed on slightly moistened white filter paper in plastic Petri dishes, closed and kept at 18°C until the flies and most of the parasitoids present had emerged. If required, extra water was added to the dishes to keep the paper slightly moist. The total number of puparia, number of emerged flies and parasitoids were recorded. Intact puparia were dissected and the presence of adult parasitoids recorded.

In trial 2, assessments of Joi Choi and Pak Choi were made on 9 and 23 March respectively. Five plants per plot of Joi Choi and Pak Choi were treated as for Pak Choi above.

Statistical analyses

For the laboratory insecticide bioassays, the proportion of surviving adults was analysed using a generalised linear mixed model (GLMM procedure in Genstat, version 8, VSN International Ltd, UK) with binomial errors, a logit link, a fixed effect for treatment, and random effects for replicate and replicate-by-treatment. The number of puparia developing was also analysed using a generalised linear mixed model with poisson errors, a log link, a fixed effect for treatment, the log of the number of mines per leaf as an offset, and random effects for replicate and replicate-by-treatment.

For the field trials, the proportion of leaves with mines was analysed using either a generalised linear model with binomial errors (if the replicate-by-treatment interaction was small) or a generalised linear mixed model with binomial errors (if the replicate-by-treatment interaction was significant). Numbers of puparia per plant were analysed using either a generalised linear model with poisson errors (if the replicate-by-treatment interaction was small) or a generalised linear mixed model with poisson errors (if the replicate-by-treatment interaction was significant).

RESULTS

Laboratory insecticide bioassays

For adult flies, mortality determinations after 48 h were more clear-cut than after 24 h and only the 48 h data were analysed. Mortality of flies in the untreated control was less than 10%. All treatments except Bt aizawai and pymetrozine caused greater mortality than the untreated control ($P<0.05$, Table 2), although the mean mortality from carbaryl and pirimicarb was only about 30%.

For fly larvae, the number of puparia emerging per leaf mine was significantly less from leaves treated by nine of the 13 insecticides than from the untreated control (Table 2). Pirimicarb appeared to kill a few larvae but the proportion of puparia emerging from the carbaryl, pymetrozine and Bt aizawai treatments was similar to that of untreated leaves.

Field trials

The first field trial used insecticides from the first ‘window’ of the diamondback moth resistance management strategy (Cameron & Walker 2005) and abamectin. Of the three cultivars sown, Joi Choi and Pak Choi had the most suitable growth forms for assessing the impact of leaf miners. Assessment methods were developed on Joi Choi and a full assessment made of Pak Choi. Abamectin-treated plants had a lower proportion

TABLE 2: Mortality of adult *Scaptomyza flava* flies (%) and emergence of puparia (number/mine) from leaves exposed to insecticides. Note that 0.01 is equivalent to zero emergence.

	Adult female flies			Larvae		
Insecticide common name	No. expts	% mortality (95% confidence limits)		No. expts	No. puparia emerging/mine (95% confidence limits)	
abamectin	2	82	(28, 98)	1	0.01	(0.00, 0.20)
acephate	2	98	(71, 99.9)	1	0.01	(0.00, 0.26)
Bt aizawai	2	2	(0.1, 25)	2	1.01	(0.67, 1.54)
carbaryl	3	30	(5, 78)	2	1.09	(0.74, 1.60)
deltamethrin	2	100	(83, 100)	1	0.01	(0.00, 0.21)
endosulfan	2	100	(84, 100)	1	0.01	(0.00, 0.26)
fipronil	2	97	(64, 100)	1	0.01	(0.00, 0.26)
indoxacarb	2	100	(84, 100)	1	0.01	(0.00, 0.24)
maldison	2	100	(82, 100)	1	0.01	(0.00. 0.31)
methamidophos	2	100	(82, 100)	1	0.01	(0.00, 0.32)
pirimicarb	5	27	(7, 64)	4	0.94	(0.66, 1.33)
pymetrozine	2	0	(0, 16)	2	1.11	(0.75, 1.65)
spinosad	2	100	(84, 100)	1	0.01	(0.00, 0.25)
untreated	10	3	(1, 8)	6	1.10	(0.80, 1.52)

of leaves with mines than those treated with other insecticides and the untreated control (P<0.001; Table 3). At harvest there were fewer mature larvae (puparia emerging over 5 days) in plants treated with abamectin, endosulfan and spinosad than in maldison-treated or untreated plants (P<0.001). Parasitoids emerged from fly puparia from all treatments.

The second field trial used insecticides from the second ‘window’ (Cameron & Walker 2005) and abamectin. Both Joi Choi and Pak Choi plants had a lower proportion of leaves with mines when treated with abamectin, deltamethrin and fipronil than those treated with indoxacarb or untreated (P<0.004; Table 4). There was no significant difference between insecticide treatments in the number of puparia from Joi Choi plants, but fewer puparia were collected from Pak Choi plants treated with abamectin, deltamethrin and fipronil than from those treated with indoxacarb or untreated (P=0.019). Parasitoids emerged from puparia from leaves of the untreated control and indoxacarb-treated plants, 74% and 40% respectively, but there were few or no puparia from the leaves of other treatments.

TABLE 3: Mean number of leaves/plant, proportion of leaves with leaf mines and mean number of puparia/plant emerging in 5 days from Pak Choi plants harvested on 18 January 2006 in trial 1.

Insecticides	Leaves/plant	% leaves with mines (95% confidence interval)		Puparia/plant (95% confidence interval)	
abamectin	20.75	15.6	(11.6–20.8)	0.64	(0.21–1.96)
endosulfan	20.42	33.0	(22.4–33.8)	0.40	(0.10–1.66)
maldison	19.33	28.0	(22.5–34.2)	3.12	(1.86–5.21)
spinosad	20.25	27.6	(27.2–39.3)	0.96	(0.38–2.42)
untreated	17.00	37.2	(30.7–44.2)	14.31	(11.19–18.30)

TABLE 4: Mean number of leaves/plant, proportion of leaves with leaf mines and mean number of puparia/plant emerging in 4 days from Joi Choi plants harvested on 9 March 2006 and Pak Choi plants harvested on 23 March 2006 in trial 2.

Insecticides	Leaves/plant	% leaves with mines (95% confidence interval)		Puparia/plant (95% confidence interval)	
Joi Choi					
abamectin	12.05	3.6	(1.4–8.8)	0	(0–0.150)
deltamethrin	11.4	6.2	(2.7–13.4)	0.04	(0.003–0.612)
fipronil	11.9	5.0	(2.1–11.3)	0	(0–0.150)
indoxacarb	12.1	13.4	(6.7–24.9)	0.84	(0.146–4.840)
untreated	10.8	20.1	(10.8–34.5)	1.68	(0.305–9.254)
Pak Choi					
abamectin	21.0	1.2	(0.5–2.9)	0	(0–0.15)
deltamethrin	21.4	4.4	(2.7–7.1)	0	(0–0.15)
fipronil	19.8	1.3	(0.5–3.1)	0	(0–0.15)
indoxacarb	20.3	24.4	(19.4–30.2)	0.09	(0.02–0.38)
untreated	20.8	31.1	(25.5–37.4)	4.84	(3.91–5.98)

DISCUSSION

Insecticides for dipterous leaf miner control are developed for Agromyzidae, not Drosophilidae, so a naïve approach was taken and representatives of all insecticides used for insect control in brassica crops were tested for efficacy against *S. flava,* though abamectin was included because it is known to give good leaf miner control (e.g. Trumble 1985; Nucifora & Calabretta 1986).

Adult and larval flies were killed by most insecticides tested in the laboratory bioassays. Of the carbamates, carbaryl killed a few adults, but no larvae, whereas pirimicarb caused some mortality of adults and larvae. *Scaptomyza flava* larvae can move to new leaves and would be expected to be vulnerable to non-translaminar or non-systemic insecticides on a leaf surface only if and when they move over the surface of leaves. However, insecticides with contact action, such as deltamethrin, appeared to kill young larvae before they would normally exit a leaf mine. Deltamethrin applied four to six times reduced infestations on European cabbage (Harris & Maclean 1999), while another synthetic pyrethroid, bifenthrin, is recommended for control of meadowfoam fly (DeFrancesco et al. 1999; Fisher & La Salle 2005). This *Scaptomyza* species is tentatively identified as *S. apicalis,* although the true *S. apicalis* is a synonym of *S. flava* (Wheeler 1978). The insecticide may be killing the adult meadowfoam flies or larvae when they move around the plant. Several synthetic pyrethroid insecticides have been used to control agromyzid leaf miners (e.g. Price & Dunstan 1983; Waddill 1986; Rushtapakornchai et al. 1996) and laboratory tests have shown that deltamethrin is toxic to larvae in mines (Richter & Tsegaye 1988; Zhang et al. 1999).

Two older insecticides, endosulfan and maldison, caused 100% mortality of adult and larval *S. flava* in the bioassays, but did not prevent leaf mine damage to Pak Choi in the field trial. Both insecticides have been used to control Agromyzidae (e.g. Jyani et al. 1995; Pawar et al. 1996), although malathion does not appear to be very effective (e.g. Singh & Merrett 1980).

Agromizid larvae are susceptible to spinosad (e.g. Saito 2004), and it has been shown to control *S. flava* in cabbages in New Zealand (Harris & Maclean 1999) and in these trials. Fipronil has been used to control agromyzid leaf miners in peas (Saito 2004) and tomato (Rushtapakornchai et al. 1996), and was effective against *S. flava* in these trials. Indoxacarb performed well in the laboratory bioassays, but appears not to be registered for leaf mining fly control and, not surprisingly, gave poor control in the field trials.

Abamectin gave good control of *S. flava* and, where it is used for leaf miner control overseas, a high proportion of parasitoids survive (Trumble 1985). Several parasitoids are known from *S. flava* (Martin al. 2004; Bjorksten et al. 2005).The most common parasitoid found in New Zealand and in the field trials was a larval/pupal parasitoid, *A. persimilis*. It emerged from fly puparia from plants in all treatments from the first trial, but there were few puparia from insecticide-treated plants in the second trial and its survival could not be assessed. It is planned to test the susceptibility of adults to residues of the insecticides.

For each field trial, the effects of insecticides on other herbivores of the brassicas are being assessed and there are plans to field-test possible IPM-based control strategies for leaf miners and the other pests of Asian brassicas.

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