Effectiveness of residual insecticides against warehouse beetle, *Trogoderma variabile* Ballion

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Abstract

The effectiveness of fresh and aged deposits of several insecticides against late-stage larvae of *Trogoderma variabile* was assessed in laboratory conditions and in an empty grain storage. Liquid treatments were applied by low-pressure spray to trays at rates deduced from control of other storage insects. Larvae were confined to deposits for 6–120 hours and were assessed for end-point mortality after recovery for up to 30 days.

Fresh deposits of organophosphates had a faster action than other treatments but declined in effectiveness more rapidly as deposits aged. Activity of fresh deposits decreased in the order chlorpyrifos-methyl or pirimiphos-methyl > azamethiphos or permethrin > deltamethrin. Carbaryl, and Dryacide® applied by slurry, were ineffective. After 32 weeks only permethrin and azamethiphos retained significant activity. Permethrin and deltamethrin deposits were more active as dusts than when wettable powder or suspension formulations were used. Activity and persistence on concrete in a grain storage and on metal ducting were variable.

The limitations and suitability of different treatments for the control of *T. variabile* larvae in storage areas and other situations are discussed.

Introduction

Trogoderma variabile Ballion, warehouse beetle, was first recognised as a significant pest in Australia in 1977 when insects were found in certain mills and sheds, and in machinery on some grain farms. Larvae were usually found in undisturbed accumulations of grain dust and were often discovered because of an abundance of cast larval skins. In cooler months larvae were able to feed and moult but moved slowly and could delay pupation for long periods in a state of facultative diapause (Hartley and Greening 1983). Infestations were also found in sunflower seed, seed warehouses and commercial premises, but not in bulk cereal grain.

The similarity of *T. variabile* to other species of *Trogoderma* with major quarantine implications led to the establishment of an eradication campaign. Control strategies were based on hygiene to remove infestable material, followed by insecticide treatment to control remaining larvae flushed from hiding. Mixtures of fenitrothion and dichlorvos were used at first, based on data of Strong (1970), but residual activity was insufficient for persistent infestations (Hartley and Greening 1983). A number of organophosphates (OPs) controlled larvae on treated inert surfaces (J M Desmarchelier, unpublished data) and chlorpyrifos-methyl was subsequently used widely. Azamethiphos was also used because of its application as a residual structural treatment in concrete grain silos against other stored grain beetles (Wallbank 1982). Infestations were markedly reduced but recurred after several years of use, particularly in empty paddy storages. Storage conditions were favourable for the development of resistance to OPs because of dust in inaccessible areas of storages and the ability of larvae to maintain diapause for long periods.

The aim of the project reported here was to assess the effectiveness of fresh and aged deposits of several available structural treatments against the current strain of *T. variabile* larvae in laboratory conditions. Selected treatments were then applied to sections of concrete and metal in field storages to confirm their effectiveness in practical conditions.

Materials and Methods

Insects

Larvae of *T. variabile* were collected from shed infestations and were held in grain fragments until eventual emergence as adults. Initial non-diapausing cultures were commenced in a coarsely ground medium of wheat, rolled oats and Savoiardi biscuits (7:2:1) at 32°C and 40–50% relative humidity in glass bottles. Adult progeny emerged after about 6 weeks and were placed in fresh medium which was left undisturbed for at least 12 weeks. The resulting crowded population with minimal available food consisted mainly of diapausing larvae. Larval cast skins were retained in these cultures to encourage diapause (Yinon 1968).

Assessment of effectiveness

After exposure to treated surfaces larvae were allowed to recover in vials of cracked wheat for up to 30 days. Larvae were classed live if able to move one body length. This extended period was necessary to ensure end-point mortality. In preliminary tests larvae exposed to some treatments could remain inactive for 15–20 days before moulting and recovering.

Residual treatments (laboratory)

Six insecticides were compared, usually at the maximum label rate registered for grain insect control in empty storages (Table 1). Insecticides were applied to metal trays (30 cm × 24 cm × 2 cm high) using a 7-L Riga sprayer and a fine spray nozzle. Trays were placed in a 10 m^2 area which was then sprayed uniformly in two passes with a total target volume of 500 mL. The actual deposit of each treatment was determined from the total volume applied and the area of each tray. After drying overnight the tray sides and rim were wiped and coated with Fluon® to prevent larvae escaping. Twenty large larvae (4–8 mg) were placed on trays at 25°C in semi-darkness and removed after exposure periods of between 6 and 120 hours. Tests were replicated three times and repeated at intervals to 32 weeks or until effectiveness declined to low levels.

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Residual treatments (field)

Azamethiphos, deltamethrin and permethrin were applied by Riga sprayer to 10 m × 50 m areas of the concrete floor and adjacent metal frame of a sub-floor auger in a storage shed (Table 1). Sufficient mixture was used for adequate coverage and an untreated area was left unsprayed. After the treatments had dried, three groups of 20 larvae were placed randomly on each treated concrete or metal area for 1 or 7 days. Insects were confined by Fluon®-coated rings which were sealed to the floor. Assessments were repeated after 1, 4 and 12 weeks from November to February. Permethrin was also tested at two rates on concrete in a second shed.

Other treatments

The effectiveness of some dusts and aerosols (Table 1) was assessed by exposing three replicates of 20 larvae to treated surfaces for 24 or 120 hours. Dusts were applied lightly (1 g/tray) and evenly to trays. Permethrin aerosol was sprayed to run-off on painted plywood and allowed to dry for 2 hours. Larvae were confined by rings treated with Fluon®. A total release aerosol ('roach bomb') of permethrin was used in a garden shed (18 m^3, 28°C) in which four untreated trays of 20 larvae had been placed on shelves. The aerosol mist developed rapidly and dissipated within 2 hours.

Results

Laboratory tests

The effectiveness of fresh deposits of the three organophosphates, azamethiphos, pirimiphos-methyl and chlorpyrifos-methyl, against *T. variabile* larvae exceeded 90% at all exposure times (Table 2). Effectiveness declined within a week for chlorpyrifos-methyl or 8 weeks for pirimiphos-methyl; only azamethiphos retained high effectiveness for 32 weeks. Permethrin also maintained high effectiveness for the length of the trial. Deltamethrin failed to control 50% of larvae with fresh or aged deposits of either formulation, even after long exposure times. Carbaryl and Dryacide® were never effective (Table 2).

Field trials

Azamethiphos retained high effectiveness for 12 weeks against larvae exposed for 1 or 7 days to treated concrete (Table 3). Deltamethrin and both rates of permethrin were also effective but declined after the first week of weathering. Azamethiphos and permethrin were highly effective for 4 weeks on metal but deltamethrin was less effective.

Other tests

Permethrin and deltamethrin dusts were highly effective for at least 8 weeks and the permethrin total release aerosol was also effective as an air-borne treatment (Table 2). The board sprayed with permethrin was ineffective.

Discussion

The laboratory trials established that fresh deposits of permethrin and of three OPs were highly effective against *T. variabile* larvae at the concentrations used. In each case the applied deposits were within 20% of the target rate based on the registered use against other hygiene insects. The relatively poor control given by deltamethrin was unexpected because of its widespread use as a hygiene treatment and because deposits were up to five times higher than the label rate. The better persistence of permethrin or azamethiphos than chlorpyrifos-methyl or pirimiphos-methyl was consistent with their formulation as wettable powders which would be less subject to degradation from surfaces than an insecticidal film. Despite this, permethrin on concrete was generally less effective than azamethiphos and did not reach the level of control achieved in the laboratory tests. Its activity appeared to be related more to the time of exposure than to the rate used and may have been affected by the concrete. Permethrin retained good activity on metal for the length of the trial and field applications on metal surfaces generally confirmed the trend in residual activity from the laboratory data except for under-treated patches.

Storage insects such as *T. variabile* may come into contact with hygiene treatments only at the time of application or when larvae wander or seek food at a later time. The distur-

Table 1. Description of laboratory and field treatments against *Trogoderma variabile* larvae.

Insecticide	Type[a]	Trade name	Formulation[b]	Deposit(mgac/m^2)	
				Lab	Field
Liquid application 0.5l/10 m^2					
Azamethiphos	OP	ALFACRON®	500gac/kg WP	330	410
Pirimiphos-methyl	OP	ACTELLIC®	900gac/L EC	325	-
Chlorpyrifos-methyl	OP	RELDAN®	500gac/L EC	370	-
Permethrin	Pyr	COOPEX®	250gac/Kg WP	150	200
Deltamethrin	Pyr	CISLIN®	10gac/L SC	40	48
Deltamethrin	Pyr	K-OTHRINE®	25gac/kg WP	27	-
Carbaryl	Car	SEPTENE®	500gac/L FL	350	-
Dryacide®	SD	DRYACIDE®	-	12500	-
Other treatments					
Permethrin dust	Pyr	COOPEX®	10gac/kg	140	-
Deltamethrin dust	Pyr	K-OTHRINE®	0.5gac/kg	7	-
Permethrin aerosol	Pyr	'Low Toxic' surface	2.79gac/kg	80	-
Permethrin aerosol	Pyr	'Roach bomb'	10gac/kg	100 mgac/m^3	

[a] OP, organophosphate; Pyr, pyrethroid; Car, carbamate; SD sorptive dust.
[b] EC, Emulsifiable concentrate; WP, wettable powder; SC, suspension concentrate; FL, flowable.

Table 2. Effectiveness of insecticides against *Trogoderma variabile* larvae in laboratory tests.

Insecticide	Exposure (hours)	Larval mortality (%)[a] after 0–32 weeks						
		0	1	2	4	8	16	32
Liquid application (Laboratory)								
Azamethiphos	(6)/120	(93)	(92)	(90)	100	100	93	95
Pirimiphos	(6)/120	(100)	(78)	(75)	100	10	2	-
Chlorpyrifos	(6)/120	(100)	(25)	(19)	5	-	-	-
Permethrin	(6)/120	(67)	(88)	100	100	100	100	100
Deltamethrin	(6)/120	(22)	47	17	39	11	-	-
Carbaryl	(6)/120	(0)	2	-	-	-	-	-
Dryacide	(6)/120	(0)	0	-	-	-	-	-
Other treatments (Laboratory)								
Deltamethrin dust	24	83	93	95	90	88	-	-
	120	100	100	98	97	95	-	-
Permethrin								
—dust	24	100	-	-	100	100	100	-
	120	100	-	-	100	100	100	-
—aerosol	24	8	5	-	-	-	-	-
	120	5	0	-	-	-	-	-
—'roach bomb'	2	96	-	-	-	-	-	-

[a] End point mortality, up to 30 days. Figures in brackets for 6 hours exposure.

Table 3. Effectiveness of insecticides applied to concrete or metal in storages against *Trogoderma variabile.*

Insecticide	Exposure (days)	Larval mortality (%)[a] after 0–12 weeks			
		0	1	4	12
Field Treatments: Concrete					
Azamethiphos	(1)/7	(93)	(100)	100	93
Permethrin	(1)/7	(42)	98	32	62
Deltamethrin	(1)/7	(38)	93	100	67
Field Treatments: Metal					
Azamethiphos	(1)/7	(98)	(100)	97	71
Permethrin	(1)/7	(83)	100	100	100
Deltamethrin	(1)/7	(63)	76	82	56

[a] End point mortality, up to 30 days. Figures in brackets for 1 day exposure.

bance of clean-up would assist in forcing active larvae to cross freshly treated barriers and thus improve the probability of receiving a lethal dose, but diapausing larvae may not contact a treated surface for considerable periods of time. Chlorpyrifos-methyl was probably effective in the eradication campaign because it had a rapid action and treatments were applied regularly. Other treatments such as azamethiphos had slower action times but much longer residual activity, and may be preferred where the target stage is the diapausing larva. The 'best' treatment may be one that has long residual activity, rapid action, and low residue. None of the liquid treatments tested satisfied all these criteria.

Pyrethroid dusts were far more effective (Table 2) than spray-applied pyrethroids. This may be related to the behaviour of the larvae which turned over onto dorsal setae when placed on treated trays. Such behaviour would assist in minimising the amount of contact with insecticide held in a static layer but would not prevent dusts from adhering to the body of the larvae. The activity of deltamethrin dust was far higher than expected from the wettable powder or suspension concentrate formulations and appeared to degrade only slightly during the period of the trial (Table 2). The strategic use of dusts applied thoroughly to cracks and crevices and other less accessible harbourages would complement general cover treatments. Permethrin dust was more effective than permethrin aerosol and would find particular application in domestic situations. The total release aerosol formulation of permethrin was effective as a disinfestation treatment against exposed larvae unable to avoid the aerosol but would be unlikely to penetrate into harbourages. For best effect, treatments should be applied after physical cleaning and removal of debris, and used as an adjunct to disinfestation agents.

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