Efficacy of several mixtures of grain protectants on paddy and maize

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Abstract

Many studies have shown that the efficacy of pairs of insecticides from different insecticide families may be greater than the sum of the effects of the individual insecticides. Commonly two protectants are used to control the suite of insects which attack Australian grain, with one protectant for control of *Rhyzopertha dominica* (F.) and the other for control of other species. The choice of protectants depends mainly on the species and strains of insect present in an area. Some results of experiments on the efficacy of several mixtures of protectants on paddy and maize are presented. The mixtures evaluated were chlorpyrifos-methyl + deltamethrin, chlorpyrifos-methyl + deltamethrin + piperonyl butoxide, or chlorpyrifos-methyl + methoprene. Resistant strains of *Sitophilus oryzae*, *S. zeamais* or *R. dominica* were used in the experiments. No significant antagonism was observed and despite some examples of synergism changes in field application rates are unlikely.

Introduction

Treatments comprising two protectants may be applied to cereal grains in Australia for protection from a suite of insect pests. The combination of protectants used depends largely on the type and prevalence of resistant populations. For example, fenitrothion + synergised bioresmethrin has been used widely for many years to control malathion-resistant insects, with synergised bioresmethrin for control of common strains of *Rhyzopertha dominica* (F.). Other protectants may be substituted to cope with different strains of this and other major species. The potential exists for synergism or antagonism in such grain protectant treatments, e.g. some studies have demonstrated synergism between organophosphorous insecticides and the pyrethroid deltamethrin (Duguet et al. 1992; Nicolas et al. 1992). This paper reports some preliminary results of experiments examining this possibility which will be published fully elsewhere. The mixtures examined were chlorpyrifos-methyl (an organophosphorous compound) with either deltamethrin (a pyrethroid) or methoprene (an insect growth regulator). In some cases the synergist piperonyl butoxide was used with deltamethrin. Chlorpyrifos-methyl was introduced as an alternative to fenitrothion particularly in response to the development of resistance in *Oryzaephilus surinamensis* (L.) (Heather and Wilson 1983; Collins and Wilson 1987). Methoprene is being used in Queensland to control *R. dominica* which have recently become resistant to bioresmethrin (Collins et al. 1993). Deltamethrin is being evaluated in large-scale field trials with the aim of registration (M. Bengston, pers. comm.).

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Materials and Methods

The protectants used were chlorpyrifos-methyl (0.5 kg active ingredient/L), deltamethrin (0.01 kg active ingredient/L), and methoprene (0.05 kg active ingredient/L). The synergist piperonyl butoxide (0.8 kg active ingredient/L) was used in some cases with deltamethrin. These emulsifiable concentrates were diluted in water and treatments were applied at the rate of 10 mL of solution to 1 kg of grain. Treatments were applied by pipette onto the inside of glass jars immediately above the grain surface. The jars were immediately sealed, briefly shaken and tumbled by hand and then tumbled mechanically for 5 minutes. The control grain received water only. Paddy and maize were conditioned to 12 and 13% respectively by addition of water and storage for 1 week for equilibration. Following treatment, moisture content was about 13% for paddy and 14% for maize.

Three species of Coleoptera were used in the experiments: *Sitophilus oryzae* (L.) (strain QS056), *S. zeamais* Motschulsky (strain QSZ103) and *R. dominica* (strain QRD63). All strains were malathion-resistant and had been reared on wheat before testing. *S. oryzae* and *R. dominica* had been selected for many years with fenitrothion, but *S. zeamais* was collected recently from the field and had not been selected before testing.

Two types of experiment were carried out on *S. oryzae* in paddy. In three experiments of the first type, paddy was treated with several application rates of one or another protectant, or various mixtures of the protectants. Paddy was treated in 250 g lots, stored overnight at 25°C, 70% r.h. then three 83 g samples were put into glass jars with filter paper lids for testing. Fifty 1–3 week old beetles were added to each jar, and after 14 days they were sieved from the paddy and assessed. After a further 8 weeks at 25°C, 70% r.h. the F_1 adults were sieved from the paddy and assessed. In two experiments of the second type, 2 kg lots of paddy were treated and stored in airtight jars at 30°C for up to 24 weeks. Three 83 g samples were taken from each treatment 1 day after treatment and at other times during storage. Tests were carried out at 25°C, 70% r.h. as described above.

Two experiments were set up to test efficacy of single protectants and mixtures of protectants against *R. dominica* and *S. zeamais* in maize stored for several months. Maize was treated in 2 kg lots and stored in airtight jars at 30°C, 70% r.h. Three 80 g samples of each treatment were taken 1 day after treatment and at other times during storage. On each occasion, 50 1–3 week old beetles were added to the maize, and adults were assessed and discarded after 14 days at 25°C, 70% r.h. After this, jars which had contained *S. zeamais* were returned to 25°C, 70% r.h. and jars which had contained *R. dominica* were put into 30°C, 70% r.h. for a further 6 weeks when the F_1 adults were removed and assessed.

Results

Deltamethrin was ineffective in experiments in which *S. oryzae* were added 1 day after treatment. Doses of 0.25, 0.5, 1

and 2 mg/kg killed 0, 0, 0 and 5.7% of adults. In contrast, deltamethrin synergised with 8 mg/kg of piperonyl butoxide was more effective, with 1.6, 14.1, 47.1 and 98.7% mortality for the corresponding doses. A dose of 5 mg/kg of chlorpyrifos-methyl produced 100% mortality in all three of these experiments (Table 1). There was significant synergism in some of chlorpyrifos-methyl + deltamethrin and chlorpyrifos-methyl + deltamethrin + piperonyl butoxide combinations, e.g. although chlorpyrifos-methyl 2.5 mg/kg gave 47.9% mortality and deltamethrin 2 mg/kg gave 5.7% together they gave 100% mortality. The number of live adult progeny ($\log_e n+1$) in treated paddy was negatively correlated with mortality of parents ($r_{24}>-0.9$), indicating that synergistic effects against parents would be reflected in the number of offspring. Methoprene was ineffective at the doses tested against parents and progeny. No significant synergism or antagonism was evident in any of the chlorpyrifos methyl + methoprene combinations.

The results described above for freshly-treated paddy are reflected in the minimum effective doses of chlorpyrifos-methyl, alone or with other compounds, for control of *S. oryzae* adults or progeny (Tables 1 and 2). The results suggest that reductions in field application rates may be possible when chlorpyrifos-methyl is combined with deltamethrin or synergised deltamethrin but not methoprene. The longer-term experiments were carried out to test this possibility.

The minimum effective application rates of chlorpyrifos-methyl, in the presence or absence of deltamethrin, for control of *S. oryzae* in tests begun 0, 6 and 12 weeks after treatment are shown in Table 3. Only results based on progeny are shown because by 6 weeks only chlorpyrifos-methyl 10 mg/kg + deltamethrin 1 mg/kg + piperonyl butoxide 8 mg/kg gave 100% mortality, and by 12 weeks mortality was <100% in all treatments. The results of the experiments on stored paddy show that significant reductions are not possible. The use of piperonyl butoxide at 8 mg/kg makes no difference in this regard. It should be noted that, although by 12 weeks none of the treatments was able to prevent live adult progeny, treatments which included 10 mg/kg of chlorpyrifos-methyl reduced the number of live progeny by >90% relative to the untreated controls.

Table 1. Minimum effective application rates of chlorpyrifos-methyl applied alone or with deltamethrin for control of *S. oryzae* in freshly-treated paddy.

Deltamethrin (mg/kg)	Adults[a]	Progeny[b]
Experiment 1		
0	>2.5–5	>5–10
0.25	>2.5–5	>2.5–5
0.5	>2.5–5	>2.5–5
1	>2.5–5	>1.25–2.5
2	>1.25–2.5	>1.25–2.5
Experiment 2		
0	>2.5–5	>1.25–2.5
0.25[c]	>2.5–5	>1.25–2.5
0.5[c]	>1.25–2.5	>1.25–2.5
1[c]	>1.25–2.5	≤1.25
2[c]	≤1.25	≤1.25

[a]Effective defined as 100% mortality.
[b]Effective defined as no live progeny
[c]Synergised with piperonyl butoxide 8 mg/kg.

Table 2. Minimum effective application rates of chlorpyrifos-methyl applied alone or with methoprene for control of *S. oryzae* in freshly-treated paddy (Experiment 3).

Methoprene (mg/kg)	Adults[a]	Progeny[b]
0	>2.5–5	>2.5–5
0.25	>2.5–5	>1.25–2.5
0.5	>2.5–5	>1.25–2.5
1	>2.5–5	>2.5–5
2	>2.5–5	>2.5–5

[a]Effective defined as 100% mortality
[b]Effective defined as no live progeny

Table 3. Minimum effective[a] application rates (in mg/kg) of chlorpyrifos-methyl applied alone or with deltamethrin on paddy for control of *S. oryzae* in tests during storage.

Deltamethrin (mg/kg)	Storage period (weeks)		
	0	6	12
Experiment 4			
0	>2.5–5	>5–10	>10
0.25	>2.5–5	>5–10	>10
0.5	≤2.5	>5–10	>10
1	≤2.5	>10	>10
Experiment 5			
0	>2.5–5	>5–10	>10
0.25[b]	≤2.5	>10	>10
0.5[b]	≤2.5	>5–10	>10
1[b]	≤2.5	>5–10	>10

[a]Effective defined as no live progeny
[b]Synergised with piperonyl butoxide 8 mg/kg.

The efficacy of various protectant treatments against *R. dominica* and *S. zeamais* in stored maize is shown in Tables 4 and 5. Deltamethrin 0.25 mg/kg + piperonyl butoxide 8 mg/kg was very effective against *R. dominica* adults and progeny, methoprene 1 mg/kg failed to control adults but gave good control of progeny, and chlorpyrifos-methyl 10 mg/kg was ineffective against this species. Chlorpyrifos-methyl and deltamethrin were both effective against *S. zeamais* but methoprene was ineffective. The mixtures of chlorpyrifos-methyl with methoprene or synergised deltamethrin gave good control of both *R. dominica* and *S. zeamais*, and there was no evidence of significant synergism or antagonism in the results.

Discussion

This paper presents results on the efficacy of mixtures of chlorpyrifos -methyl (an organophosphorous compound) with deltamethrin (a pyrethroid) or methoprene (an insect growth regulator) against several species of Coleoptera. Antagonism did not appear to be important in any of the mixtures and, although synergism was observed in some cases, changes in field application rates are unlikely.

Examples of synergism were seen in paddy tested with *S. oryzae* 1 day after treatment with chlorpyrifos-methyl + deltamethrin or chlorpyrifos-methyl + synergised deltamethrin. Nicolas et al. (1992) and Duguet et al. (1992) also found positive interactions between organophosphorous insecticides and deltamethrin. In addition they found that although piperonyl butoxide synergised deltamethrin it tended to antagonise organophosphorous insecticides. In other tests the

Table 4. Percent mortality of parents and reduction in F_1 adults in tests after treatment of maize with chlorpyrifos-methyl (CM), deltamethrin + piperonyl butoxide (DM + PB), and chlorpyrifos-methyl + synergised deltamethrin (CM + DM + PB) (Experiment 6).

Treatment (mg/kg)	Storage (weeks)	*R. dominica*		*S. zeamais*	
		Mortality	F_1 reduction	Mortality	F_1 reduction
CM 10	0	8.9	a	100	100
	18	-	-	100	99.1
DM 0.25 + PB 8	0	100	100	97.3	96.9
	18	100	99.8	90.6	96.1
CM 10 + DM 0.25 + PB 8	0	100	100	100	100
	18	100	100	100	100

[a]More than 20 progeny

Table 5. Percent mortality of parents and reduction in F_1 adults in tests after treatment of maize with chlorpyrifos-methyl (CM), methoprene (MP) and chlorpyrifos-methyl + methoprene (CM + MP) (Experiment 7).

Treatment (mg/kg)	Storage (weeks)	*R. dominica*		*S. zeamais*	
		Mortality	F_1 reduction	Mortality	F_1 reduction
CM 10	0	1.5	a	100	99.8
	18	–	–	100	96.0
MP 1	0	4.5	95.3	0.0	a
	18	1.4	98.9	–	–
CM 10 + MP 1	0	0.1	97.2	100	100
	18	4.8	99.8	100	98.4

[a]More than 20 progeny

author has found that piperonyl butoxide at 8 mg/kg did not affect efficacy of chlorpyrifos-methyl against *S. oryzae* in paddy (Daglish, unpublished data).

In Australia the registered application rates for more than 3 months storage are 10 mg/kg for chlorpyrifos-methyl and 1 mg/kg for methoprene. The likely application rate of deltamethrin is 0.25 mg/kg with 8 mg/kg of piperonyl butoxide (M. Bengston, personal communication). None of the long-term experiments on paddy or maize suggests that changes in application rates are likely. Other studies of mixtures of protectants applied at registered or likely application rates support these findings. Desmarchelier (1977) evaluated some mixtures against *R. dominica*, *Tribolium castaneum* (Herbst), *T. confusum* (Jacq. du Val) and *S. oryzae* in wheat; and found that there was no significant interaction between any of the organophosphorous insecticides (dichlorvos, fenitrothion and pirimiphos-methyl) and synergised pyrethrins, bioresmethrin or synergised bioresmethrin. In stored maize Arthur et al. (1990) found that chlorpyrifos-methyl + methoprene was no better than chlorpyrifos-methyl alone against *T. castaneum*, *S. zeamais*, *Cryptolestes pusillus* (Schönherr) and *Plodia interpunctella* (Hübner). In another study on stored maize Duguet et al. (1992) found that chlorpyrifos-methyl + deltamethrin was similar in potency against *S. zeamais* to chlorpyrifos-methyl + deltamethrin + piperonyl butoxide.

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