Organophosphorous and synergised synthetic pyrethroid insecticides as grain protectants for stored maize

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Abstract

Organophosphorothiates and synergised synthetic pyrethroids were tested in field trials for the protection of maize in commercial silos at Johor Baharu Flour Mill, Pasir Gudang, Malaysia. Laboratory bioassays of treated grain samples at intervals over 9 months established the following orders of effectiveness against *Sitophilus oryzae* (L.), *Sitophilus zeamais* (L.), *Rhyzopertha dominica* (F.), *Tribolium castaneum* (H.) and *Oryzaephilus surinamensis* (L.): fenitrothion 12 mg/kg + fenvalerate 0.5 mg/kg + piperonyl butoxide 8 mg/kg > deltamethrin 1 mg/kg + piperonyl butoxide 8 mg/kg = pirimiphos-methyl 6 mg/kg + permethrin 1 mg/kg + piperonyl butoxide 8 mg/kg > chlorpyrifos-methyl 10 mg/kg + bioresmethrin 1 mg/kg + piperonyl butoxide 8 mg/kg. The first three grain protectant combinations completely prevented production of progeny of the five beetle species for 4.5–9 months. Against quarantine species *Trogoderma granarium* (E.), treatments containing organophosphorous insecticide were effective in preventing progeny for 3–4.5 months, but complete mortality was limited to immediately after treatment.

The implication of the above investigations indicate that imported or local maize harvest, if treated with grain protectants at the earliest stage, can be protected against insect infestations for the whole duration of commercial handling of the raw grain.

Introduction

Malaysia currently imports about 750000 t of maize annually (Anon. 1989), to support industries related to animal feed, cooking oil, confectionery, and for other domestic requirements. The grain is imported in bulk, stored in concrete and metal silos (each 200–2000 t capacity) at the port terminals, before being processed at adjoining mills into cooking oil and animal feed formulations, or distributed in bags to other food processors, either wholesalers or retailers. Cross-infestations from older maize and other types of grain frequently occur, mainly by *Rhyzopertha dominica*, *Sitophilus zeamais*, and other secondary species, mainly *Tribolium castaneum* (Yunus 1970). Control measures are based on routine fogging of the premises with insecticides but heavy infestations are fumigated with phosphine.

In collaboration with the Australian Centre for International Agricultural Research (ACIAR), a series of trials was conducted in 1990–91, to evaluate several combinations of insecticides as protectants against infestations during the time between importation and consumption of the raw grain. This paper discuss the results of findings on the effectiveness of the treatments, and implications for the overall quality management of grain in the food industry in Malaysia.

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Materials and Methods

Treatment and storage of grain

The treatments were carried out at Johore Baharu Edible Oil Grain receival and storage complex, near Pasir Gudang Port in Johore. This privately owned storage complex was equipped with 15 concrete and metal silos, with storage capacity varying from 200 to 1500 t. Emulsifiable concentrates of organophosphorothiates (OP), synthetic pyrethroids (SP) and piperonyl butoxide (PB) were used. Details of the treatments are given in Table 1. The OPs used were appropriate to control all commonly occurring storage beetles except *R. dominica*, which requires a SP as well as an OP insecticide. Each insecticide was diluted with water, then combined with the companion insecticide in a vat. The protectants were sprayed into the grain stream on a belt conveyor at the rate of 1 L/t during loading of the grain into aerated silos for the commencement of storage. Due to market demand, the storage period in the silos was shortened to 2–3 months, with the remainding storage (up to 9 months) in 0.3 t bins.

Table 1. Summary of treatments on application of insecticide admixtures in grain maize in concrete silos at Johore Baharu Flour Mill, Pasir Gudang.

Insecticide	Dosage (mg/kg)	Date of treatment	Maize treated (t)
Pirimiphos-methyl + permethrin + piperonyl butoxide	6 + 1 + 8	14/2/90	100
Fenitrothion + fenvalerate + piperonyl butoxide	12 + 0.5 + 8	15/2/90	100
Deltamethrin + piperonyl butoxide	1 + 8	16/2/90	100
Chlorpyrifos-methyl + bioresmethrin piperonyl butoxide	10 + 1 + 8	17/2/90	100

Sampling of grain

Sampling of the grain at the treatment site was done at two locations: i) on the conveyor belt during loading into the silo before and after treatment; and ii) from 1.5 m below the surface at 1.5-month intervals. The pretreatment samples from the conveyor were taken to compare grain moisture and temperature with the treated grain, and for bioassays. Samples from the grain surface were taken using a vacuum sampler at 12 sampling points in each silo, then bulked, subdivided and sealed in sample tins.

Measurement of storage moisture and temperature

Grain moisture was measured from pre- and post-treatment grain, and at the surface in the silo (or bin) at each sampling date using a Protimeter® moisture meter. Grain temperature during treatment was recorded from subsamples taken from the grain stream during treatment, using electronic thermometers (YSI probes), while that of grain in silos (or bins) was measured by probing the sensor 1.5 m below the surface.

Bioassays

Laboratory bioassays were carried out on six species of malathion-resistant grain beetles: *Sitophilus oryzae*, *S. zeamais*, *R. dominica*, *T. castaneum*, *Oryzaephilus oryzaephilus* and *Trogoderma granarium*. Fifty unsexed adults beetles of < 3 weeks old (larvae for *T. granarium*) were assayed in each of three replicates containing 83 g of treated or untreated (control) grain. Mortality of test insects was recorded at 3 and 26 days, and progeny production was recorded for the F_1 and F_2 generations after 10 and 16 weeks, respectively. The interval during which no progeny were produced was calculated for each generation based on suppression of F_1 and F_2 progeny.

Results and Discussion

Storage temperature and grain moisture

Mean grain moisture contents and temperatures are shown in Table 2. There were no significant changes in grain moisture or the temperature of the grain. Any significant increase in insect growth and development will be reflected by increases in grain temperature and moisture, resulting in loss of activity of the protectants, and deterioration of the grain conditions (Samson 1985; Bengston et al. 1990). Grain temperatures monitored inside the aerated silos (storage up to 2–3 months) and from the smaller bins showed similar variations throughout the storage period, in the range of 30–35°C. No significant changes were observed on the grain moisture of the treated and untreated grain throughout the storage period. This observation was in agreement with published studies on effect of application of grain protectants on grain (Desmarchelier et al. 1987; Arthur et al. 1990). A slight drying effect with longer storage period was observed, as reflected by decreases in grain moisture from 12% initially to 10–11% after 9 months storage. Both grain temperature and moisture were within safe limits, indicating no grain deterioration as result of application of grain protectants and long-term storage.

Bioassays

The intervals of complete protection for each treatment determined for both complete mortality of adults and complete prevention of progeny production are given in Tables 3 and 4, respectively.

All treatments, except synergised deltamethrin against *T. granarium*, completely prevented the production of progeny (F_2 generation) for at least 3 months against all the test insects. Fenitrothion plus fenvalerate was the most effective, with complete control achieved throughout the 9 months storage against the common grain beetles *S. oryzae, S. zeamais, R. dominica, T. castaneum, and O. surinamensis*. The longer period of progeny prevention for this treatment was reflected by the 100% mortality of the parent adults at 26 days. In Australia, field trials using fenitrothion (12 mg/kg) plus (1R)-phenothrin (1 mg/kg) on wheat and barley showed similar periods of protection against malathion-resistant *T. castaneum* and susceptible and OP-resistant strains of *R. dominica* (Desmarchelier et al. 1987). Laboratory trials with fenitrothion at the same application rate had, however, given only 3 months prevention of F_2 progeny production with *T. castaneum* (Samson and Parker 1989b).

Synergised deltamethrin and pirimiphos-methyl plus synergised permethrin both generally provided similar periods of protection (6–9 months) against *S. oryzae, R. dominica*, and *O. surinamensis*. The exceptions were the shorter period of protection obtained against *S. zeamais* in the former treatment (4.5 months), and against *T. castaneum* in the latter (3 months). Earlier studies on deltamethrin treatment with PB revealed variations in susceptibility among different strains of *S. oryzae* and *S. zeamais*. (Heather 1986; Samson et al. 1990).

Our results also indicate that the period of protection against *T. castaneum* by the combination of pirimiphos-methyl plus permethrin was shorter than that shown by previous laboratory studies on maize (Samson and Parker 1989b), where pirimiphos-methyl treatment at a lower rate (4 mg/kg) was effective for 9 months. However, against *R. dominica*, the performance of the SP component in our treatment combinations was in agreement with Samson and Parker's results on the individual unsynergised SPs, where deltamethrin (0.04 mg/kg), fenvalerate (0.25 mg/kg), and permethrin (0.5–1 mg/kg) gave complete protection for 9 months, but rates higher than 1 mg/kg as used in this study, were required using bioresmethrin.

Table 2. Mean temperatures and grain moisture contents of maize during storage.

Treatment	Mean grain moisture content (%) during storage (months)							Mean temperature (°C) during storage (months)						
	0	1.5	3.0	4.5	6.0	7.5	9.0	0	1.5	3.0	4.5	6.0	7.5	9.0
Pirimiphos-methyl + permethrin + piperonyl butoxide	10.4	na	10.5	9.5	12.1	10.6	9.8	29.5	30.6	32.2	30.0	28.8	30.0	33.6
Fenitrothion + fenvalerate + piperonyl butoxide	12.4	na	11.0	10.3	12.1	10.1	9.8	31.8	31.6	32.8	31.2	28.6	28.4	30.4
Deltamethrin + piperonyl butoxide	12.4	na	9.8	10.3	12.1	11.4	11.7	32.9	32.6	33.0	31.8	31.2	33.6	35.6
Chlorpyrifos-methyl + bioresmethrin + piperonyl butoxide	12.2	na	9.3	9.5	12.2	10.5	10.7	32.2	32.6	32.4	32.0	31.4	35.8	34.4
Untreated	11.8	na	10.9	10.3	12.3	13.3	11.1	33.9	na	na	32.6	31.4	33.2	35.0

na = not available

Table 3. Period of complete mortality (months) achieved by insecticide admixtures in controlling storage beetles in bioassays with treated bulked maize.

Treatments	Complete mortality after 3 days (insect species)						Complete mortality after 26 days (insect species)					
	SO	SZ	RD	TC	OS	TG	SO	SZ	RD	TC	OS	TG
Pirimiphos-methyl + permethrin + piperonyl butoxide	6	3	1.5	0	1.5	0	7.5	7.5	1.5	3	3	0.2
Fenitrothion + fenvalerate + piperonyl butoxide	0.2	3	1.5	1.5	9	0	9	9	9	9	9	0.2
Deltamethrin + piperonyl butoxide	6	0	1.5	0	7.5	0	6	6	1.5	6	7.5	0
Chlorpyrifos-methyl + bioresmethrin + piperonyl butoxide	4.5	3	1.5	1.5	1.5	0	4.5	3	1.5	1.5	3	0.2

SO — *Sitophilus oryzae*
RD — *Rhyzopertha dominica*
OS — *Oryzaephilus surinamensis*
SZ — *Sitophilus zeamais*
TC — *Tribolium castaneum*
TG — *Trogoderma granarium*

Table 4. Period of complete mortality (months) achieved by insecticide admixtures in controlling storage beetles in bioassays with treated bulked maize.

Treatments	Complete prevention of F_1 generation						Complete prevention of F_2 generation					
	SO	SZ	RD	TC	OS	TG	SO	SZ	RD	TC	OS	TG
Pirimiphos-methyl + permethrin + piperonyl butoxide	6	6	4.5	1.5	6	1.5	6	6	7.5	3	6	3
Fenitrothion + fenvalerate + piperonyl butoxide	9	6	9	3	9	1.5	9	9	9	9	9	4.5
Deltamethrin + piperonyl butoxide	6	4.5	7.5	1.5	7.5	0	6	4.5	9	6	7.5	0
Chlorpyrifos-methyl + bioresmethrin + piperonyl butoxide	4.5	3	1.5	1.5	1.5	1.5	4.5	3	4.5	3	4.5	3

SO — *Sitophilus oryzae*
RD — *Rhyzopertha dominica*
OS — *Oryzaephilus surinamensis*
SZ — *Sitophilus zeamais*
TC — *Tribolium castaneum*
TG — *Trogoderma granarium*

Chlorpyrifos-methyl plus synergised bioresmethrin was the least effective, providing a maximum of 4.5 months protection to all test insects. This is in agreement with earlier studies against *S. oryzae* on maize (Samson and Parker 1989b), and against *T. castaneum* on maize and paddy rice (Samson and Parker 1989a). In the United States, various field trials using chlorpyrifos-methyl on stored maize showed that it provided good control for periods of 8 to 21 months against *S. zeamais* and *T. castaneum* (La Hue 1976, 1977; Arthur et al. 1990; Arthur 1992). However, their assessment of efficacy was based on relative reduction of infestations.

Grain storages in Malaysia have been gazetted free from *T. granarium* following detection of infestations and their subsequent suppression in the mid 1980s in several milled rice storages in northern Peninsular Malaysia (Anon. 1985). Its control was included in this study in anticipation of a recurrence of infestations in maize. Our results indicate that the duration of complete mortality of larvae was limited to samples taken immediately after treatment with insecticide combinations containing OP insecticide. However, F_2 progeny could be completely suppressed for 3–4.5 months with these treatments.

Conclusion

Our studies show that, with a single application of water-diluted emulsifiable insecticides direct to the grain at the beginning of grain handling, protection against insect infestations can be achieved for the duration of handling and storage of the raw grain within the local marketing chain. The residual insecticides control both *in situ* and future invading populations through mortality of parent adult (or larvae) and complete prevention of progeny. Thus, grain protectants will prevent spread of infestations through movement of grain. In addition, this protective measure may yield substantial savings by reducing possible losses of grain and costs of fumigation. The latter control measure currently cannot be efficiently or safely conducted in large mills and storage, due to poor sealing of the silos, or bag storage practices.

We estimate that treatment with grain protectants will cost $AU0.80/t; 78% of this for insecticides, the rest for equipment, labour, and fuel.

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