Trials of grain protectants on stored maize under Philippine conditions

M.A. Acda, P.B. Sayaboc, A.G. Gibe and C.B. Gragasin*

Abstract

In the Philippines, maize is severely infested in storage by *Sitophilus zeamis, Rhyzopertha dominica* and *Tribolium castaneum*. Treatment combinations were selected on the basis of laboratory experiments, with the aim of giving complete protection from insect infestation during 9 months storage.

Treatments were applied by admixture as the grain was moved from one bin to another on the premises of the National Food Authority at General Santos City in Mindanao. Following treatment, the grain was bagged and transported to Cebu City, simulating industry practice. Grain moisture content was 13%.

Efficacy was measured by challenging with insects in the laboratory samples of treated grain taken at 1.5-month intervals throughout storage. In addition, the insect population, percent insect damaged grain and percent weight loss were estimated on each sampling occasion and at the completion of storage.

The following treatments gave virtually complete protection throughout the storage: chlorpyrifos methyl 8 mg/kg + deltamethron 0.4 mg/kg; chlorpyrifos methyl 10 mg/kg + methoprene 2.0 mg/kg; fenitrothion 10 mg/kg + d-phenothrin 1 mg/kg + piperonyl butoxide 10 mg/kg; and pirimiphos methyl 8 mg/kg + permethrin 1 mg/kg + piperonyl butoxide 10 mg/kg.

The untreated grain averaged 2600 insects per kg, 14.3% insect-damaged kernels and 6.5% weight loss at the completion of storage.

Introduction

In the Philippines, maize is stored under humid conditions highly conducive to insect infestation, and serious losses occur unless effective treatments are applied (Caliboso et al. 1985). Currently most storage is in bags (polypropylene or jute of 50 kg capacity) and control measures are based chiefly on store hygiene, grain fumigation and surface treatment of bag stacks with residual insecticides. With the introduction of bulk storage, admixture of insecticides directly into the grain will become practicable, protecting grain for the full storage period.

Malathion-resistant strains of the major pest species are prevalent in the Philippines and the efficacy of malathion is greatly reduced (Sayaboc and Acda 1990). Laboratory studies on these insects suggested that newer grain protectants are more potent but field trial indicated that combinations of insecticides are needed to control all members of the pest complex (Sayaboc et al. 1987). These studies also produced estimates of minimum effective doses required for complete protection from infestation during 9 months of storage.

* National Post Harvest Institute for Research and Extension, Muñoz, Nueva Ecija, Philippines.

This paper reports a field experiment aimed at validating the efficacy of candidate treatments suggested by the preliminary studies. The maize was treated by spraying insecticide into the grain stream as it moved through a drying facility. The treated maize was then bagged and held in commercial storage. Residues were measured analytically and the efficacy was measured by both laboratory bioassay and estimation of infestation levels and weight loss of maize in storage.

Methodology

Grain treatment and storage

White maize was treated in a commercial grain drying facility at General Santos City in Mindanao. The maize was of commercial quality and contained from 5–8% damaged grain, 0.6–0.9% foreign matter, 1.5–3.6% immature shrivelled kernels and had a bulk density of 755 to 777 g/L. The insecticides used (Table 1) were chlorpyrifos-methyl, deltamethrin, d-phenothrin, fenitrothion, methoprene, permethrin, piperonyl butoxide and pirimiphos-methyl. The insecticides were diluted with water and sprayed into the grain stream (1 L/t) during movement of the grain from one metal bin to another. Each treatment took 12–15 hours.

Following treatment, the grain was bagged into 50 kg polypropylene sacks and shipped by sea to a commercial storage constructed from concrete and galvanized iron in Cebu City. Storage commenced 1.5 months after treatment.

The control treatment was the industry standard used at the discretion of pest control personnel. In the current case, one fumigation was carried out after three months storage, using 3 g of phosphine per cubic metre, generated from aluminum phosphide.

For each treatment, an initial composite sample of grain was obtained by taking small sub-samples from the grain stream at 5-minute intervals during treatment. A second composite sample was obtained using a grain trier to sample each bag during building of the bag stacks. During storage, 36 marked bags were sampled at 6-week intervals and samples were combined to give composite samples designated as top stack, side of stack, inner stack and centre of stack. At the termination of storage, a composite sample was prepared by sampling each bag.

Grain moisture was measured on sub-samples of ground grain using an oven drying method (130°C for 60 minutes). Grain temperature was measured daily throughout storage using eight thermocouples built into each stack.

Natural insect infestation

During storage, insect infestation was estimated by sieving a 500 g composite sample at each sampling occasion, from top of stack, side of stack, inner stack and centre of stack. At the end of storage, insect infestation was estimated by sieving all grain in 100 bags from each treatment using an inclined sieve to separate the insects from the grains.

Insect damage and dry weight loss of grain

Detailed grain analyses were carried out at the beginning and end of the experiment. For each treatment a 500 g composite sample was sorted manually and classified as sound, damaged, immature, germinated, mouldy or an off-variety. Bulk density was measured using a chondrometer (Harris and Lindblad 1976). In addition, the bulk density and insect damage measurements were repeated every 6 weeks interval throughout storage. Measurement was replicated three times in each sampling occasion. The bulk density was then used to estimate the weight loss of grain during the experiment.

Laboratory bioassays

Test species were the rust-red flour beetle [*Tribolium castaneum* (Herbst)], the lesser grain borer [*Rhyzopertha dominica* (F)], the maize weevil, (*Sitophilus zeamais* Motschulsky) and the khapra beetle, [*Trogoderma granarium* (Everts)]. Malathion resistance levels determined by impregnated paper assays were >500× for *T. castaneum* and >10× for *R. dominica*, at the $KD_{99.9}$.

Bioassays were carried out on the composite samples from each treatment including untreated controls. In each of 3 replicates, 50 beetles (1–3 weeks old) were added to 100 g of grain and the response was assessed after 3 and 26 days exposure at 25°C and 70% r.h. The basis of response was knockdown, described as the inability of the insect to walk in a coordinated manner. All insects were removed at 26 days and the grain was moved to 30°C, and F_1 and F_2 progenies were recorded after 10 weeks and 16 weeks, respectively.

Response of the insects in the treated samples was corrected for control mortality using Abbotts formula. Percentage reduction in progeny was calculated by comparing the number of progeny in each treatment with the controls. A treatment was judged to give complete protection against test insects if no living progeny was produced, and suppression of test insects achieved if progenies did not exceed the number of parents introduced.

Residue analysis

Samples of whole grain (40 g) replicated twice were extracted overnight using petroleum ether (50 mL) for pyrethroids and chlorpyrifos-methyl. Acetone-acetic acid (99+1 by volume) was used in extracting residues of the other organophosphorous insecticides. Residues were estimated by either an electron-capture detector for pyrethroids or a flame photometric detector for organophosphates following gas liquid chromatography.

Results and Discussion

Grain temperature in storage

The grain temperatures recorded in the core region of each stack of the treatments in Cebu City are illustrated in Figure 1. There was evidence that grain temperatures rose with infestation in the control stack and declined following fumigation at three months. Temperatures in grain from the treatments reflected ambient conditions.

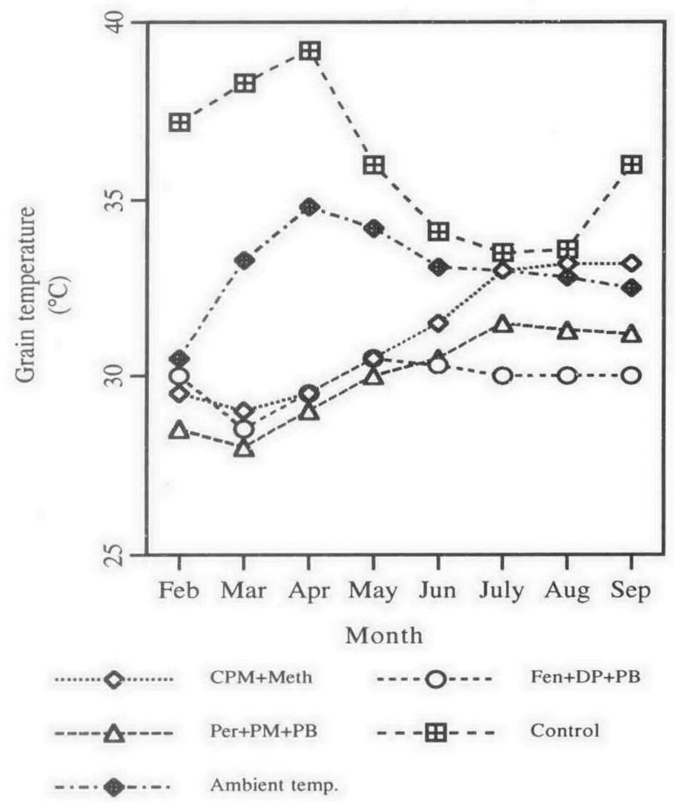

Fig. 1. Mean grain temperature in the core region of each stack of treated maize stored at Cebu City.

Natural insect infestation

The mean number of insects per 500 g of maize for each of seven pest species present at termination of the experiment is given in Table 2.

Table 1. Maize grain used, moisture content, temperature and insecticide treatments.

Quantity of grain (t)	Initial moisture content of grain (%)	Date treated	Treatment rate	Concentration of insecticide in original formulation (g/L)	Formulation
193.70	12.76	6.12.88–7.12.88	Chlorpyrifos-methyl 8 mg/kg	200	SC
			+ deltamethrin 0.4 mg/kg		SC
191.24	12.93	4.12.88–5.12.88	Chlorpyrifos-methyl 10 mg/kg	225	EC
			+ methoprene 2.0 mg/kg	500	EC
229.84	13.22	26.11.88–27.11.88	Fenitrothion 10mg/kg	500	EC
			+ d-phenothrin 1 mg/kg	100	EC
			+ piperonyl butoxide 10 mg/kg	930	EC
227.92	12.84	5.12.88–6.12.88	Pirimiphos-methyl 8 mg/kg	250	EC
			+ Permethrin 1 mg/kg	100	EC
			+ piperonyl butoxide 10 mg/kg	930	EC

Generally, very few insects were present in the treated stacks as compared with the fumigated control treatment. Damaging population levels of *R. dominica* were present in the industry standard treatment. Most importantly, no *T. granarium* were present in any treatment. Also very few primary pests were found.

Overall population of pests in the fumigated control stack reached an average of 2600 insects/kg, while mean pest numbers in the treated stacks were from 23.18–88.3/kg at the completion of the storage.

Insect damage and dry-weight loss of grain

The level of insect damage observed at the end of the experiment, and the estimated dry-weight loss from bulk density measurements, are given in Table 3. On both criteria, all treatments significantly reduced all levels of damage. Considering dry-weight loss, chlorpyrifos-methyl in combination with methoprene was superior to fenitrothion plus synergised d-phenothrin and pirimiphos-methyl plus synergised permethrin. On the other hand, chlorpyrifos-methyl plus deltamethrin was better than fenitrothion plus synergised d-phenothrin.

Laboratory bioassays

Data are summarised as the intervals of complete prevention or suppression of infestation in Table 4.

In most cases, complete protection was provided for the full duration of the experiment. In instances where complete prevention was not achieved, suppression of the progenies was attained. Significantly, the prevention of the highly destructive *T. granarium* was complete for all treatments throughout the storage period. The best treatment was chlorpyrifos-methyl 8 mg/kg plus deltamethrin 0.4 mg/kg which gave effective control of all species for 9 months.

Residue analysis

Data on the calculated application rates based on the weights of grain and the volumes of diluted pesticide applied, and the residue level determined analytically in samples taken immediately after treatment, are given in Table 5. They suggest that insecticide recovery of 59 to 76% of the calculated application rates during treatment was better than the percentage recovery attained during the first trial, which was 20 to 78%.

Data on residue levels during storage are given in Table 6. Residue levels for all compounds were lower at the com-

Table 2. Insect infestation in maize 9 months after treatment in General Santos City (mean number per kg).

Treatment	*Trogoderma granarium*	*Sitophilus zeamais*	*Rhyzopertha dominica*	*Tribolium castaneum*	*Oryzaephilus surinamensis*	*Latheticus oryzae*	*Cryptolestes ferrugenius*	Total
Chlorypyrifos-methyl 8 mkg/kg + deltamethrin 0.4 mg/kg	0	0.06	0.50	42.56	0.16	0.36	0	43.61
Chlorpyrifos-methyl 10 mg/kg + methoprene 2 mg/kg	0	0	6.50	35.76	0.30	0.40	1.70	45.66
Fenitrothion 10 mg/kg + d-phenothrin 1 mg/kg + piperonyl butoxide 10 mg/kg	0	0	1.66	17.4	0.96	2.20	0.96	23.18
Pirimiphos-methyl 10 mg/kg + permethrin 1 mg/kg + piperonyl butoxide 10 mg/kg	0	0.16	2.00	20.56	0	0.40	0.40	23.52
Control (industry standard)	28.80	0	427.2	1295.40	10.80	591.00	252.64	2605.84

Table 3. Percentage of grain with viable insect damage and the dry-weight loss estimated from bulk density measurements of experiment (9 months)[a].

Treatment	Insect damage (%)	Dry-weight loss (%)
Chlorpyrifos-methyl 8 mg/kg + deltamethrin 0.4 mg/kg	3.87[ab]	1.67[ab]
Chlorpyrifos-methyl 10 mg/kg + methoprene 2 mg/kg	6.74[b]	1.29[a]
Fenitrothion 10 mg/kg + d-phenothrin 1 mg/kg + piperonyl butoxide 10 mg/kg	3.44[a]	2.94[c]
Pirimiphos-methyl 10 mg/kg + permethrin 1 mg/kg + piperonyl butoxide 10 mg/kg	4.18[ab]	2.33[bc]
Control (industry standard)	14.28[c]	6.45[d]

[a]Any two means having a common letter were not significantly different at 5% level.

Table 4. Intervals of complete prevention or suppression of infestation of test insects in laboratory bioassays on treated maize stored in bags at Cebu City.

Treatment	Interval of complete prevention[a] (or suppression)[b] of progeny on different test insects (months)							
	R. dominica		*S. zeamais*		*T. castaneum*		*T. granarium*	
	a	b	a	b	a	b	a	b
Chlorpyrifos-methyl 8 mg/kg + deltamethrin 0.4 mg/kg	9.0[c]	(-)	9.0[c]	(-)	9.0[c]	(-)	9.0[c]	(-)
Chlorpyrifos-methyl 10 mg/kg + methoprene 2 mg/kg	2.5	(9.0[c])	5.5	(9.0[c])	7.0	(9.0[c])	9.0[c]	(-)
Fenitrothion 10 mg/kg + d-phenothrin 1 mg/kg + piperonyl butoxide 10 mg/kg	9.0[c]	(-)	9.0[c]	(-)	5.5	(9.0[c])	9.0[c]	(-)
Pirimiphos-methyl 10 mg/kg + permethrin 1 mg/kg + piperonyl butoxide 10 mg/kg	9.0[c]	(-)	9.0[c]	(-)	7.0	(9.0[c])	9.0[c]	(-)

[a] 100% reduction in F_2 progeny
[b] $F_2 < 50$
[c] maximum duration of this experiment

Table 5. Calculated application rates and residues measured analytically on maize sampled immediately after treatment.

Treatment	Calculated application rate (mg/kg)	Residue immediately after treatment (mg/kg)	Recovery (%)
Chlorpyrifos-methyl 8 mg/kg	7.35	5.60	76
+ deltamethrin 0.4 mg/kg	0.37	0.25	67
Chlorpyrifos-methyl 10 mg/kg	10.12	7.60	75
+ methoprene 2 mg/kg	2.02	-	-
Fenitrothion 10 mg/kg	10.57	6.45	61
+ d-phenothrin 1 mg/kg	1.06	0.70	66
+ piperonyl butoxide 10 mg/kg	-	-	-
Pirimiphos-methyl 10 mg/kg	7.86	4.67	59
+ permethrin 1 mg/kg	0.98	0.62	63
+ piperonyl butoxide 10 mg/kg	-	-	-

Table 6. Residues on treated maize stored in bags in horizontal storage in Cebu City for varying periods (months) after spray application

Treatment	1.5	3	4.5	6	7.5	9
Chlorpyrifos-methyl 8 mg/kg	3.56	2.32	2.16	1.34	0.33	0.35
+ deltamethrin 0.4 mg/kg	0.18	0.12	0.13	0.06	0.06	0.06
Chlorpyrifos-methyl 10 mg/kg	3.43	3.00	1.40	1.08	0.70	0.50
+ methoprene 2 mg/kg	-	-	-	-	-	-
Fenitrothion 10 mg/kg	2.60	1.70	1.30	1.15	1.0	0.32
+ d-phenothrin 1 mg/kg	0.44	0.45	0.35	0.33	0.31	0.25
+ piperonyl butoxide 10 mg/kg	-	-	-	-	-	-
Pirimiphos-methyl 10 mg/kg	3.07	2.30	2.25	2.33	1.87	1.59
+ permethrin 1 mg/kg	0.46	0.37	0.411	0.24	0.22	0.23
+ piperonyl butoxide 10 mg/kg	-	-	-	-	-	-

mencement of storage than in the initial sample, presumably due to decay during shipment of the grain and to initial losses of insecticides during pesticide application. In spite of the sampling variability inevitable in a field experiment of this nature, the rates of breakdown observed were generally similar to those of controlled studies reported elsewhere (Desmarchelier et al. 1979).

Conclusion

Insect infestation in maize in the current experiment was very low which reduced losses of grain weight by 45% to 80% compared with control stacks.

Using the criteria of insect damage and weight loss, the combinations of insecticides, chlorpyrifos-methyl plus deltamethrin and chlorpyrifos-methyl plus methoprene were equally effective. However, with regards to complete prevention of infestation, chlorpyrifos-methyl plus deltamethrin which provided complete protection in all test insects for the maximum duration of the experiment was significantly superior to all other treatments.

References

Caliboso, F.M., Sayaboc, P.D. and Amoranto, M.A. 1985. Pest problems and the use of pesticides in grain storage in the Philippines. In: Champ, B.R. and Highley, E., ed., Pesticide and Humid Tropical Grain Storage Systems. ACIAR Proceedings No. 14, 17–30.

Desmarchelier, J.M., Bengston, M. and Sticka, R. 1979. Stability and efficacy of pyrethrum as grain in storage. Pyrethrum Post, 15, 3–8.

Harris, K.L. and Linblad, C.J. 1976. Postharvest Grain Loss Assessment Methods. 86–89.

Sayaboc, P.D. and Acda, M.A. 1990. Resistance of the major coleopterous pests of stored grain to malathion and pirimiphos-methyl. Philippine Entomologist 8 (1), 653-660.

Sayaboc, P.D., Acda, M.A., Cano, F. and Gibe, A.G. 1987. Evaluation of grain protectants on stored maize. In: de Mesa, B.M., ed., Proceedings of the 10th Asean Technical Seminar on Grain Postharvest Technology, 150-163.