INVESTIGATION INTO THE USE OF RESMETHRIN AND BIORESMETHRIN AS POTENTIAL GRAIN PROTECTANTS

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ABSTRACT: Results of grain protectant trials comparing resmethrin and bioresmethrin with synergised pyrethrins and with malathion are discussed. Trials utilised commercial welded-steel silos of 5 tonne capacity of a type commonly used for 'on-farm' grain storage, and were held over a period of eight years commencing in 1967. Treated wheat, in five tonne lots, was sampled at monthly intervals and subjected to bioassays of 7, 14 and 28 day duration. F_1 and in some cases F_2 generation counts were also made.

Treatments of 2.0 ppm resmethrin plus 20.0 ppm piperonyl butoxide; bioresmethrin at 4.0, 8.0 and 12.0 ppm; bioresmethrin/piperonyl butoxide at 0.5/5.0 ppm, 1.0/10.0 ppm, 4/20 ppm and 8/20 ppm; bioresmethrin 2.0 ppm plus antioxidant at 0.2 ppm were compared with similar treatments of 12.0 ppm malathion and/or 2.0 ppm pyrethrins plus 20.0 ppm piperonyl butoxide.

For long-term storage the most cost/effective treatment used was 4.0 ppm bioresmethrin plus 20.0 ppm piperonyl butoxide. After twelve months storage the treated grain controlled *Rhizopertha dominica*, 2 susceptible and 2 resistant strains; *Sitophilus granarius*, 1 resistant strain; *S. oryzae*, 2 susceptible and 1 resistant strain; *Oryzaephilus surinamensis*, *Plodia interpunctella* and *Ephestia cautella*. A much lower efficiency was observed in the control of *Tribolium* species and in this regard bioresmethrin parallels the documented insecticidal efficiency of pyrethrins.

The occurrence in Australia of several organo-phosphorus insecticide resistant strains of *R. dominica* poses a severe threat to the grain handling industry. It now appears that bioresmethrin as a potential candidate protectant should be able to restore broad spectrum control, the noted exception being *Tribolium* species. Bioresmethrin is significantly less toxic to mammals than pyrethrins for which there is an established tolerance on grain at 3.0 ppm. Similarly there is a tolerance of 20.0 ppm for piperonyl butoxide on grain.

INTRODUCTION: The recent development of pyrethroid insecticides

has shown that at least one, bioresmethrin, or 5-benzyl-3-furyl-methyl d trans chrysanthemate [1], holds promise for direct application to food stuffs as a highly effective grain protectant [2]. These studies show that bioresmethrin and bioresmethrin plus piperonyl butoxide (1:10 ratio) is superior, with one exception, to pyrethrins or pyrethrins/piperonyl butoxide or resmethrin or resmethrin/piperonyl butoxide against *Tribolium castaneum* and susceptible or resistant strains of *Sitophilus granarius*. Against resistant *S. granarius* resmethrin plus piperonyl butoxide was equally as effective as bioresmethrin plus piperonyl butoxide.

The problem of resistance to malathion (Malathion*) which is developing in stored product insects has caused intensive examination of alternative protectant chemicals. The only alternative with international sanction and approval for use on cereal grains is pyrethrins synergised by piperonyl butoxide. The price of pyrethrins in comparison with malathion has resulted in comparatively minor usage of synergised pyrethrins as a grain protectant.

Detection of resistance follows the method established by Champ [3]; modifications were later made by F.A.O. [4] and other workers [5]. It should be noted that the method operates as an 'early warning system' and that the practical significance in field populations is not to be readily deduced.

As predicted by Parkin [6] in 1964, resistance has not developed as rapidly among stored product insects as among public health and agricultural insects. Among the reasons given, the use of fumigation must rank high in importance. Not mentioned, however, is the value of hygiene and sanitation in all types of storage facility.

Trials in 1967/68 showed good activity by resmethrin and bioresmethrin, with advantages for the latter. The subsequent spread of resistance in Australia amongst 'primary insect pests' of grain such as *Rhizopertha dominica* and *Sitophilus* spp. stimulated interest in bioresmethrin because of its good safety potential. Rates of application were increased mainly to gauge effect on the tolerant *Tribolium* species. Virtually no grain is stored in Australia for any length of time without using a protectant.

MATERIALS AND METHODS: All trials were carried out at the Wellcome Research Station, St. Marys, New South Wales, Australia. The facility comprises four ten tonne steel, elevated and self emptying silos, each divided into two five tonne bins. Four inspection ports were added to each bin.

The experimental emulsifiable concentrates were diluted with water and applied using a COOPER grain sprayer comprising electric motor, pump with bypass and pressure gauge plus on/off tap on the spray wand. The wand was attached to the head of the auger and the spray was directed into the grain stream falling through the hatch into the bin. All equipment and the method are available and currently used by grain farmers.

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Grain was sampled using a CORCORAN type grain sampler, two metres long and with a 450 g capacity. Grain temperature was measured using a RADSON temperature probe and grain moisture was measured using a MARCONI TF 933A moisture meter. Grain was sampled as soon after treatment as convenient and then at monthly intervals. Samples were taken from five points on the surface and at one metre and two metres depth below each point, each was sieved for insects and then bagged as a common level sample.

Bioassays were made using a 130 g sample of wheat drawn in equal quantities from each of the three levels, adding insects and recording the mortality in 14 days time. Cultures of susceptible *R. dominica*, *S. granarius*, *S. oryzae* and *T. castaneum* were reared under controlled conditions of 24°C and 70% to 75% relative humidity. Wide mouthed jars with ventilated screw top lids were used to contain treated grain and samples of 100 adults of mixed age of test species. The F_1 generation was assayed by removing all adults for the bioassay count at 14 days and incubating for a further 30 days. A count was then made of adult insects both dead and alive.

Control storage of malathion-free wheat became heavily infested after three to four months storage and were therefore abandoned. Standard comparative treatments of 12.0 ppm malathion or 2.0 ppm pyrethrins plus 20.0 ppm piperonyl butoxide were considered of more value in assessing the relative efficiency of experimental treatments.

Additional bioassays were carried out using both susceptible and resistant strains held at the Division of Entomology, C.S.I.R.O., Canberra. Batches of 50 adult Coleoptera aged one to six weeks were placed on 80 g of treated wheat or for *Tribolium* species, 140 g of treated wheat. All cultures were then kept at 25° C and 55% R.H. for 26 to 28 days. The adults were then all removed, except for *S. granarius* and re-located at 30°C and 55% R.H. Counts of F_1 progeny were taken 10 weeks after the start of the bioassay at which time the adults were removed. The F_2 progeny were counted a further six weeks later. For Lepidoptera 50 eggs were placed on 140 g treated wheat at 30°C and 70% R.H. Emerged adults were counted after six weeks. Resistance factors were not monitored. All bioassays were duplicated.

The following additional strains were tested using the above procedures: *R. dominica*, CRD 2, a standard susceptible strain, CRD 118, a general organo-phosphorus resistant strain which breeds on grain freshly treated with 18.0 ppm malathion or 12.0 ppm dichlorvos [7] [8]; *S. oryzae*, CLS 2, a standard susceptible strain originating from the Pest Infestation Laboratory, Slough, UK [7], CSO 231, a general resistant strain which breeds on grain freshly treated with 6.0 ppm malathion and 6.0 ppm dichlorvos [8]; *S. granarius*, CSG12, a specific malathion resistant strain [7]; *T. confusum* CTOs, a susceptible strain; *T. castaneum* CTC 12, a general resistant strain, CTCs, a susceptible strain; *Oryzaephilus surinamensis* OSs, a susceptible strain [8] and field strains of *Plodia interpunctella* and *Ephestia cautella*.

RESULTS: The results of trials are condensed in Table I and will be presented in detail later [9]. On the basis of length of storage and cost/efficiency the most effective treatment was 4.0 ppm bioresmethrin plus 20.0 ppm piperonyl butoxide.

TABLE I. Summary of pyrethroid grain protectant trials 1967-1974.

Year of Trial	Treatment	Grain Storage Particulars: Holding Period (months)	Grain Moisture %(average)	Grain Temperature °C(average)	Final Laboratory Assay: Bioassay % Mortality(a) Sgs	Rds	Tcs	F1 Generation(actual numbers) Dead: Sgs	Rds	Tcs	Live: Sgs	Rds	Tcs
1967	2.0 ppm resmethrin + 20.0 ppm p.b.o.	11.25	11.4	20.6	100	100		0	0		0	0	
	in comparison with: 2.0 ppm pyrethrins + 20.0 ppm p.b.o.	10	11.5	20.7	85	100		1	0		0	0	
1968	1.0 ppm bioresmethrin + 10.0 ppm p.b.o.	4	≏ <10.0	29.0	99	100	0	1	0	0	0	0	0
	0.5 ppm bioresmethrin + 5.0 ppm p.b.o.	4	≏ <10.0	28.4	100	100	40	1	0	0	4	0	0
	in comparison with: 2.0 ppm pyrethrins + 20.0 ppm p.b.o.	3	≏ <10.0	20.6	95	100	20	0	0	2	10	0	1
1969	2.0 ppm bioresmethrin + 0.2 ppm antioxidant	8	10.9	19.2	75	100	40	0	0	0	50	10	9
	in comparison with: 12.0 ppm malathion	8	10.8	20.7	100	80	90	23	0	0	0	1	0
1973/74	4.0 ppm bioresmethrin	12	10.2	23.9	(b)5	100	<8(c)	0	0		63	0	
	8.0 " "	12	10.7	24.0	40	100	<15	0	0		3	1	
	12.0 " "	12	10.5	24.4	95	100	<38	2	0		0	0	
	4.0 " " + 20.0 p.b.o.	12	10.5	23.5	100	100	<10	1	0		0	0	
	8.0 ppm bioresmethrin + 20.0 p.b.o.	12	10.5	23.6	100	100	<9	0	0		1	1	
	in comparison with: 12.0 ppm malathion	12	10.4	23.9	95	0	<8	3	1		0	6	
	CONTROL BIOASSAY				4	5		0	4		396	0	

KEY: Sgs - *Sitophilus granarius*)
Rds - *Rhizopertha dominica*) Susceptible
Tcs - *Tribolium castaneum*) Strains

(a) 14 day period
(b) *S. oryzae* in all 1973/1974 trials
(c) *T. castaneum* assays discontinued after nine months

Samples of eleven, twelve or thirteen month old treated grain from the 1973/1974 trials were bioassayed by Dr. J. M. Desmarchelier using both susceptible and resistant cultures and will also be reported later in detail [9]. Results are presented in condensed form, using the 4.0/20.0 ppm, bioresmethrin/piperonyl butoxide treated grain, in Table II. Procedures basically followed those already outlined.

DISCUSSION: In Australia the occurrence of malathion-resistant strains of *R. dominica* is a severe threat to the grain export industry. The efficiency of bioresmethrin or bioresmethrin/piperonyl butoxide combinations in controlling this species is therefore important, and Table II shows their efficiency against a resistant strain. In comparison, the *Sitophilus* species are tolerant of unsynergised bioresmethrin as indicated by 5%, 40% and 95% mortality for 4.0, 8.0 and 12.0 ppm of bioresmethrin respectively in contrast to 100% mortality at twelve months storage for 4/20 ppm bioresmethrin/piperonyl butoxide (Table I).

The percentage control of *Tribolium castaneum* adults is very low in Table I, higher in Table II, and reflects the tolerance of this species for synergised pyrethrins. Factors influencing the biological efficiency of pyrethrins on grain have never been fully resolved. Survival of the F_1 generation is very small in

TABLE II. Additional assays using 4.0 ppm bioresmethrin plus 20.0 ppm piperonyl butoxide treated grain against important insect pests of wheat.

Species	Susceptible(S) or Resistant(R)	Age of Treated Grain (months)	Bioassay: 7 day	Bioassay: 28 day	F1 Generation Survival as % of control	F2 Generation as a % of F1
Rhizopertha dominica	S (CRD 2)	12	100	100	0	
	R (CRD 118)	12	100	100	0	
Sitophilus oryzae	R (CSO 231)	12	98	100	0	0
	S (CLS 2)	11	98	100	0	0
Sitophilus granarius	R (CSG 12)	12	100	100	0	0
Tribilium castaneum	R (CTC 12)	11		98	0	
	S (CTC s)	12		98	0	
Tribolium confusum	S (CTO s)	12		49	0	
Oryzaephilus surinamensis	S	13		100	0	0
Ephestia cautella	Field strain	13			0	
Plodia interpunctella	Field strain	13			0	

Table I, counted at six weeks and zero in Table II, counted four weeks later. Joubert [10] reported similar suppression of *T. castaneum* F_1 generation by synergised pyrethrins on maize grain.

Bioresmethrin is significantly less toxic to mammals than pyrethrins [1], but an accurate method for determining residues in grain is required.

Tribolium spp. excepted, 4 ppm bioresmethrin plus 20 ppm piperonyl butoxide gave better control of all species and strains examined, after twelve months storage of wheat, than did 12 ppm malathion or 2 ppm pyrethrins plus 20 ppm piperonyl butoxide.

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