USE OF PIRIMIPHOS-METHYL FOR THE CONTROL OF STORED RICE INSECT PESTS IN S.E. ASIA*

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ABSTRACT: Trials evaluating pirimiphos-methyl, a new wide spectrum organo-phosphorus insecticide with low mammalian toxicity, against pests of stored rice in S.E. Asia are described. The experiments discussed here were concerned with the admixture of insecticide with grain and also the external treatment of hessian sacks used for storing rice.

For the treatment of external surface of the sack an application of 250-500 mg a.i./m.sq. pirimiphos-methyl controlled all insect pests entering the sacks for up to 6 months after treatment.

An admixture treatment at 4 ppm similarly controlled the pests present and protected against insects entering the sacks for up to six months after treatment.

Pirimiphos-methyl combines a strong fumigant effect with a lasting contact activity.

In Malaysian trials the standard malathion treatment at equivalent and higher rates were ineffective against the main pest *Tribolium castaneum*, suggesting development of resistance to this chemical.

Pirimiphos-methyl was also found to give effective and prolonged control of other pests e.g. *Oryzaephilus surinamensis*, *Sitophilus oryzae*, *Ephestia cautella*, *Rhizopertha dominica* and *Sitotroga cerealella*.

INTRODUCTION: Infestation of insects and mites is a serious problem in the storage of grains, particularly under tropical environments. In S.E. Asian countries a large proportion of stored rice is kept in bags in godowns under conditions of severe infestation causing losses and deterioration of the grain quality.

Normal control measures to guard against these pests include fumigation of incoming stocks with methyl bromide and the use of malathion and lindane as protectants during storage. Control with fumigants, however, is short-lived and resistance to malathion in some of the important pests such as *Tribolium castaneum* is very

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*2-diethylamino-6-methyl pyrimidin-4-yl dimethyl phosphorothionate was synthesized by I.C.I. Plant Protection Ltd in 1967. Initially it was given the code number PP511, and in 1970 the British Standard Institution common name of pirimiphos-methyl.

common.

Pirimiphos-methyl, a wide spectrum organo phosphorus insecticide of low mammalian toxicity (LD_{50} Female Rats 2050 mg/kg) has been shown to have high activity against beetles, weevils and moths commonly infesting stored products. Its rapid action and persistence on inert surfaces, e.g. hessian sack, walls and masonry, has further suggested its use for the control of the pests of stored products.

This paper describes results from trials evaluating efficacy of pirimiphos-methyl either as an external treatment of sacks used for storing rice or in admixture with grain.

MATERIALS AND METHODS: Padi and milled rice samples 0 - 3 months old, were used in all the experiments. Bags before and after treatment were stored in godowns at a temperature of 25-35°C. The main pests in trials carried out in Malaysia and Indonesia included *Tribolium castaneum, Oryzaephilus surinamensis, Sitophilus oryzae, Rhiphopertha dominica, Ephestia cautella* and *Sitotroga cerealella.*

Spraying of Sacks - Clean jute sacks were sprayed using a knapsack sprayer fitted with ceramic tip T-jet. Pirimiphos-methyl emulsion (25% or 50% a.i. formulation) was diluted in water and sprayed to obtain a deposit of 250, 500 and 1000 mg a.i./m.sq. The chemical was applied either to both top and bottom surfaces or only to the top surface of the sack. A minimum of two replicates of three bags were used. After treatment the bags were stored as small stacks, exposed to the same pest population as the remainder of the stock in the godown outside the trial area. The total capacity of godowns varied between 3,000-15,000 tons.

Samples of 400-500 grams at day 0 and thereafter at monthly intervals after spraying were withdrawn either using a spear or after thoroughly mixing the contents of the whole bag. After completing the counts of dead and live insects in these samples, a 100 gram sub-sample was sent for residue analysis.

Admixture with Grain - An emulsion and a dust formulation of pirimiphos-methyl were used in the admixture trials and were applied to give dosages of 2, 4, and 8 ppm. The 25% emulsifiable concentrate was diluted with acetone and sprayed on to the padi or rice grains using the method described above. The volume rate of diluted solution used was 10 mls/10 lb of padi. The 2% a.i. dust formulation was directly admixed with the grain.

Admixture trials were carried out only in Malaysia. The main pest, as in the case of bag spraying trials, was *T. castaneum.* Treated grains were packed in small 10 lb bags which were stored in 2 bag stacks in the main godown. Seven such bags were prepared for each treatment.

For biological assessment one 10 lb bag was withdrawn at day 0 and thereafter at monthly intervals. Insect counts were carried out on a sub-sample of 400 grams, and when the biological assessments were completed a 100 gram sample was sent for residue analysis.

In the Malaysian trials malathion at equivalent rates was

included as the standard, whereas in Indonesia, the presently used practice of fumigation with methyl bromide was adopted as the standard.

Residue Analysis - Samples withdrawn for residue analysis were sent to Jealott's Hill Research Station of Plant Protection Ltd in England where determinations were carried out using the Gas Liquid Chromatography method of analysis with a limit of detection at 0.01 ppm. (Details of procedure No. INS 70 developed by Plant Protection Ltd are available on request).

RESULTS: Spraying of Sacks - Counts of live and dead adults of the main insect pests observed in trials are presented in Tables I, II and III. At all the rates evaluated in these trials pirimiphos-methyl gave good control of all the species present in the sack and was more active than malathion.

TABLE I. Counts of *Sitophilus oryzae* present in grain sample at intervals following insecticide application to the surfaces of the sacks.

Treatment	Rate a.i./m.sq.	4 Weeks		12 Weeks		20 Weeks		32 Weeks	
		Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Pirimiphos-methyl	250 mg.*	0	0	2	0	5	2	20	8
Pirimiphos-methyl	500 mg.**	2	0	1	1	9	0	16	2
Malathion	250 mg.*	2	0	2	0	20	7	38	75
Malathion	500 mg.**	0	2	9	1	5	5	15	62
Malathion	1000 mg.**	12	6	9	0	35	9	65	37
Control	-	4	0	7	1	15	8	30	71

* Chemical application to both top and bottom surfaces of sacks.
** Chemical application to top surface of sacks only.

Malathion treatments even at 1000 mg a.i. m.sq. failed to provide control of *Tribolium castaneum* indicating high level of resistance to this chemical.

Admixture Trials - An emulsion and a dust formulation of pirimiphos-methyl were admixed at 2, 4 and 8 ppm with either milled or unmilled grain.

With milled rice, data presented in Table IV, the emulsion formulation of pirimiphos-methyl gave better control of *T. castaneum* than was obtained with the dust formulation, particularly at 2 and 4 ppm. At the higher rate of 8 ppm both the formulations were equally active until 24 weeks after application. At 28 weeks the

TABLE II. Counts of *Rhizopertha dominica* present in grain samples at intervals following insecticide application to the surface of the sacks.

Treatment	Rate a.i./m.sq.	4 Weeks		12 Weeks		20 Weeks		32 Weeks	
		Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Pirimiphos-methyl	250 mg.*	22	2	32	0	29	1	60	10
Pirimiphos-methyl	500 mg.**	6	0	16	1	22	1	101	18
Malathion	250 mg.*	28	8	33	2	33	5	79	27
Malathion	500 mg.**	24	2	18	2	45	2	75	27
Malathion	1000 mg.**	26	2	28	2	34	5	87	31
Control	-	32	4	23	6	30	2	77	32

* Chemical applied to both top and bottom surfaces of sacks.
** Chemical applied to the top surface of sacks only.

number of live *Tribolium* in the bags treated with the dust formulation began to increase.

With unmilled grain the differences in activity between the two formulations and rates against *Tribolium* and *Rhizopertha*, were not very clear (Table V and VI), although the control was better than malathion at all the rates.

Residue Analysis - Bag Spraying Treatments: Residue data from Indonesian and Malaysian trials are presented in Table VII.

In the Malaysian trials on rice samples from whole bags, following treatments at 250 and 500 mg a.i./m.sq., gave generally low residues, the highest being 1.80 ppm one week after treatment.

Similar low levels were also observed in the Indonesian trials.

- Admixture Treatment: Residue levels in polished grain after admixture treatment are presented in Table VIII. With the emulsion formulation, high levels were observed particularly at 8 ppm but these dropped after 2-3 months.

With the unmilled grain most of the residues at all rates were found to be in the husk and the rice showed levels well below 1 ppm at all times (Table IX).

In the case to be reviewed by the Codex Committee on Pesticide Residues the recommended temporary tolerance of pirimiphos-methyl in rice with husk is 6 ppm and in polished rice is 2 ppm.

DISCUSSION: In most cases fresh padi or milled rice samples entering a godown are free of pests. However, once in the godown the grain comes under attack from pests being harboured there. Ideally, therefore, the chemical treatment should prevent the entry

TABLE III. Counts of *Tribolium castaneum* present in grain samples at intervals after insecticide application.

Treatment	Rate a.i./m.sq.	4 Weeks		12 Weeks		20 Weeks		28 Weeks	
		Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Pirimiphos-methyl	250 mg.*	130	0	12	2	170	4	267	16
Pirimiphos-methyl	500 mg.**	106	0	111	0	208	2	273	7
Pirimiphos-methyl	1000 mg.**	66	2	116	0	162	1	340	0
Malathion	250 mg.*	12	18	18	13	30	30	50	14
Malathion	500 mg.**	32	16	24	17	30	12	45	5
Malathion	1000 mg.**	40	16	51	16	38	29	44	13
Control	-	18	40	22	32	27	39	55	18

* Chemical applied to top and bottom surfaces of sacks.

** Chemical applied to top surfaces of sacks only.

TABLE IV. Counts of *Tribolium castaneum* present in rice grain samples at various intervals following insecticide admixture

Treatment		Rate	4 W.A.T.		12 W.A.T.		20 W.A.T.		28 W.A.T.	
			Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Pirimiphos-methyl	E.C.	2 ppm	366	11	934	19	809	24	723	169
Pirimiphos-methyl	E.C.	4 ppm	498	0	1373	1	984	0	773	8
Pirimiphos-methyl	E.C.	8 ppm	673	0	1047	0	1193	0	673	1
Malathion	E.C.	2 ppm	52	406	224	539	428	228	142	474
Malathion	E.C.	4 ppm	74	186	146	364	148	325	40	170
Malathion	E.C.	8 ppm	93	119	82	220	87	177	73	209
Control		-	98	729	138	470	92	158	90	239
Pirimiphos-methyl	Dust	2 ppm	269	52	1029	80	1435	206	698	313
Pirimiphos-methyl	Dust	4 ppm	328	13	1797	72	1121	29	2853	1020
Pirimiphos-methyl	Dust	8 ppm	434	9	3653	1	1525	7	2046	104
Malathion	Dust	2 ppm	47	287	77	204	54	99	160	438
Malathion	Dust	4 ppm	35	78	77	185	64	126	77	198
Malathion	Dust	8 ppm	45	72	66	170	46	110	102	259
Control		-	87	144	76	225	41	91	78	289

W.A.T. = Weeks After Treatment

TABLE V. Counts of *Tribolium castaneum* present in unmilled grain samples at various intervals following insecticide admixture.

Treatment		Rate	4 W.A.T		12 W.A.T		20 W.A.T		28 W.A.T.	
			Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Pirimiphos-methyl	E.C.	2 ppm	208	0	132	4	179	15	181	4
Pirimiphos-methyl	E.C.	4 ppm	77	1	131	0	354	6	241	5
Pirimiphos-methyl	E.C.	8 ppm	241	0	635	0	467	0	395	0
Malathion	E.C.	2 ppm	19	33	36	20	35	7	45	4
Malathion	E.C.	4 ppm	17	25	20	8	38	10	52	8
Malathion	E.C.	8 ppm	80	44	23	3	46	29	35	2
Pirimiphos-methyl	Dust	2 ppm	129	0	461	2	231	6	143	9
Pirimiphos-methyl	Dust	4 ppm	2	2	234	0	249	0	178	4
Pirimiphos-methyl	Dust	8 ppm	131	0	285	0	236	0	569	6
Malathion	Dust	2 ppm	26	6	30	26	23	6	35	17
Malathion	Dust	4 ppm	23	12	45	11	21	8	41	5
Malathion	Dust	8 ppm	24	8	20	20	25	9	25	7
Control		-	28	18	20	10	35	30	30	7

W.A.T. = Weeks After Treatment

TABLE VI. Counts of *Rhizopertha dominica* present in unmilled grain samples at various intervals following insecticide admixture.

Treatment		Rate	4 W.A.T		12 W.A.T		20 W.A.T		28 W.A.T.	
			Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Pirimiphos-methyl	E.C.	2 ppm	18	1	57	0	38	11	69	8
Pirimiphos-methyl	E.C.	4 ppm	26	1	26	1	36	2	69	19
Pirimiphos-methyl	E.C.	8 ppm	45	1	60	1	92	7	33	7
Pirimiphos-methyl	Dust	2 ppm	57	3	139	1	47	22	73	15
Pirimiphos-methyl	Dust	4 ppm	102	6	126	1	77	8	49	11
Pirimiphos-methyl	Dust	8 ppm	88	1	115	0	25	1	75	16
Malathion	E.C.	2 ppm	12	2	38	11	99	19	57	15
Malathion	E.C.	4 ppm	40	2	43	9	117	33	82	27
Malathion	E.C.	8 ppm	58	0	44	12	115	49	91	19
Malathion	Dust	2 ppm	52	1	69	5	48	15	56	50
Malathion	Dust	4 ppm	121	7	120	2	74	15	61	31
Malathion	Dust	8 ppm	83	0	74	1	142	44	43	16
Control		-	69	7	27	7	69	34	48	18

W.A.T. = Weeks After Treatment

TABLE VII. Pirimiphos-methyl residues in rice after bag treatment.

Location	Pirimiphos-methyl formulation	Rate applied to bags mg ai/m.sq.	Residues found ..... interval after treatment ppm				
			Up to 1 week	1 month	2 months	3 months	4 months
Malaysia	25% EC	250 500	1.33 1.80	0.22 0.46	0.22 0.49	0.11 0.36	
Indonesia (Tjirebon)	50% EC	250	0.17 0.14	0.17 0.25	0.06 0.17		
(Lampung)	"	250 500	0.10 0.07		**0.23** 0.68	0.11 0.21	0.33 0.44
(Bandung)	"	250 500	0.04 0.10	0.22 0.12	0.37 0.56	0.22 0.24	0.90 2.64

Limit of detection 0.01 ppm

TABLE VIII. Residue analysis data from polished grains after insecticide admixture treatment.

Treatment		Rate	Residue in ppm				
			0 DAY	1 MTH	2 MTH	3 MTH	4 MTH
Pirimiphos-methyl	E.C.	2 ppm	1.55	0.75	1.12	1.21	0.4
Pirimiphos-methyl	E.C.	4 ppm	3.05	2.03	2.00	2.08	0.8
Pirimiphos-methyl	E.C.	8 ppm	5.00	3.60	3.60	3.32	1.57
Pirimiphos-methyl	Dust	2 ppm	1.29	0.89	0.45	0.38	0.22
Pirimiphos-methyl	Dust	4 ppm	2.20	1.28	1.34	0.89	0.41
Pirimiphos-methyl	Dust	8 ppm	3.92	2.08	2.40	2.04	1.29
Malathion	E.C.	2 ppm	0.54	0.05	0.02	-	-
Malathion	E.C.	4 ppm	0.69	0.07	0.04	-	-
Malathion	E.C.	8 ppm	1.4	0.17	0.07	-	-
Malathion	Dust	2 ppm	-	0.25	0.04	-	-
Malathion	Dust	4 ppm	-	0.54	0.11	-	-
Malathion	Dust	8 ppm	-	1.33	0.25	-	-
Control		-	0.0	0.0	-	-	-

MTH = Month

TABLE IX. Residue analysis data from unmilled grains after insecticide admixture treatment

Treatment	Rate	Residue in ppm									
		0 DAY		1 MTH		2 MTH		3 MTH		5 MTH	
		Husk	Grain	Husk	Grain	Husk	Grain	Husk	Grain	Husk	Grain
Pirimiphos-methyl	2 ppm E.C.	3.06	0.17	2.08	0.08	1.85	0.09	1.60	0.17	1.75	0.10
Pirimiphos-methyl	4 ppm E.C.	6.06	0.25	4.16	0.16	3.91	0.20	2.66	0.26	3.7	0.12
Pirimiphos-methyl	8 ppm E.C.	12.6	0.63	9.04	0.31	8.3	0.50	6.62	0.85	6.96	0.21
Pirimiphos-methyl	2 ppm Dust	1.58	0.07	1.56	0.06	4.1	0.12	1.48	0.11	1.47	0.15
Pirimiphos-methyl	4 ppm Dust	2.40	0.08	2.80	0.08	6.5	0.18	2.20	0.25	3.50	0.09
Pirimiphos-methyl	8 ppm Dust	-	-	4.16	0.10	14.6	0.48	4.0	0.40	6.64	0.15
Malathion	2 ppm E.C.	3.08	0.08	1.36	0.05	-	-	-	-	-	-
Malathion	4 ppm E.C.	8.64	0.14	2.88	0.09	-	-	-	-	-	-
Malathion	8 ppm E.C.	30.8	0.65	9.12	0.34	-	-	-	-	-	-
Malathion	2 ppm Dust	4.72	0.10	0.80	0.05	-	-	-	-	-	-
Malathion	4 ppm Dust	7.68	0.11	0.81	0.05	-	-	-	-	-	-
Malathion	8 ppm Dust	12.32	0.18	1.81	0.09	-	-	-	-	-	-
Control	-	0.0	0.0	0.0	0.0	-	-	-	-	-	-

MTH = Month

of insects by killing or repelling the invaders quickly to prevent both breeding and the accumulation of live adults. Results presented in this paper suggest that pirimiphos-methyl was not only able to provide rapid control of species like *T. castaneum* but also effectively prevented the pest from entering the sacks.

Activity greater than or equal to malathion, bromophos, iodofenphos, tetra-chlorvinphos, dichlorvos and fenitrothion, as shown by minimum effective doses, was observed in laboratory tests against several important pests including *S. oryzae, O. surinamensis, R. dominica,* susceptible and resistant strains (kano strain of malathion specific resistance and Australian non-specific resistance) of *T. castaneum* (Anon. 74). High activity of pirimiphos-methyl against common pests was fully confirmed by the results presented here.

In the laboratory, hessian strip treated with 250 mg/m.sq. gave 100% kill of *E. kuhniella* adults for 14 weeks after treatment compared with only 10% kill by fenitrothion at 100 mg/sq.ft. The present study once again confirmed the long persistence of pirimiphos-methyl on jute sacks as reinfestation was prevented for nearly six months after a single application.

Malathion treatments even at the high rate of 100 mg/m.sq. gave much poorer control of *T. castaneum* than would have been expected based on the LD 50 value from the tropical application test. It seems very likely, therefore, that the population of *Tribolium* present in the Malaysian godowns has developed a strong resistance to malathion treatments.

In the present study both applications to the sack surface as well as admixture treatments were evaluated and found to be effective in controlling the pests. However, the protective sack sprays gave lower residue levels, particularly with milled rice, and are, therefore, preferred over the admixture treatments. The fumigant activity of pirimiphos-methyl (vapour pressure approximately 1×10^{-4} Torr at 30° C) coupled with its high intrinsic activity will ensure that the invading pest is controlled before it can oviposit. Nevertheless, with the sack treatment alone it is considered desirable not only to treat each sack as it arrives for storage but also to spray all surfaces in the godown to control the hidden pest population.

In the case of the admixture treatment of unmilled grain the bulk of the residues were found in the husk leaving rice relatively free of the chemical even one month after spraying. This method of application may, therefore, be more appropriate in situations with heavy populations of pests able to bore into the husk of the grain, e.g. *Rhizopertha* sp. and *Sitophilus oryzae.*

To summarise, pirimiphos-methyl has been shown to be highly effective in providing rapid control of a wide range of stored products pests including a malathion resistant strain of *T. castaneum.* Its long persistence on hessian sacks enabled excellent protection of the grain over a long period.

For the treatments of the external surface of the sack a 250-500 mg/m.sq. rate and for admixing a 4 ppm rate should give

rapid control and prolonged protection against the common pests of stored unmilled and milled rice.

REFERENCE:

Anon. March 1974, Technical Data Sheet, 'Actellic' containing pirimiphos-methyl: An insecticide for stored products. Plant Protection Ltd, Fernhurst, U. K.