THE EFFECTIVENESS OF METHACRIFOS APPLIED TO WHEAT OR RICE IN CONTROLLING TWO SPECIES OF GRAIN WEEVIL

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Abstract

The organophosphate pesticide methacrifos was tested against *Sitophilus granarius* and *S. oryzae* when applied to wheat or rice. On wheat, a dose of 2.3 mg/kg gave superior suppression of progeny production of *S. granarius*, when compared with chlorpyrifos-methyl, etrimfos and pirimiphos-methyl. A dose of 9 mg/kg was also effective in preventing the production of progeny for 20 weeks at 25° C, when applied to brown rice. This dose also gave good control of adults exposed to the treated grain over a 16 week period. A dose of 4.5 mg/kg was initially equally effective but persisted for a shorter period. Analysis of residues over a 24 week period showed that they declined by about 70%.

INTRODUCTION

Grain weevils are common and destructive pests of stored grain. The adult female bores a small hole in a grain and deposits an egg, then seals the hole with a waxy plug. Upon hatching, the larva tunnels into the grain and goes through its entire development concealed within the kernel, finally emerging as a fully developed adult, and leaving behind a grain which is often completely hollow. Consequently, weevil infestations may not be detected until large numbers of insects have emerged, and serious damage to the grain has resulted.

Current recommendations for the control of weevils include fumigation or the application of pesticides directly to the grain. Fumigation can be very effective, provided the toxic gas can be contained within the grain bulk for sufficient time. However, this type of treatment offers no residual protection, requires highly skilled operators and is relatively expensive. Admixture techniques can usually be performed by grain store staff, offer a period of protection from a single treatment and are usually less expensive than fumigations.

Because of these advantages, much laboratory and field testing of pesticides suitable for admixture has been done. However, generally most tests against weevil species have used adult insects, so that, data about their effect on the immature stages are limited. Rowlands (1975); Rowlands and Bramhall (1977) showed that aliquots of most organophosphorus pesticides applied to grain remain in the seed coat and aleurone layers, little penetrating into the endosperm where the majority of the development of the immature weevils takes place. Thus, it is likely that immature stages of this insect may not come into contact with the pesticide until they emerge.

Limited studies have indicated that the organophosphate pesticide methacrifos shows particular efficacy against immature weevils. Consequently, the present work was carried out to compare the efficacy of methacrifos with three other organophosphate pesticides widely used as grain protectants, in controlling the immature stages of *S. granarius* developing within wheat grains. Additional studies were also undertaken to show the efficacy of methacrifos when applied to rice grains in controlling adult *S. oryzae* and suppressing the production of progeny.

METHODS

1. Wheat experiment

For the purposes of this experiment, the life cycle of *S. granarius* was divided into the following stages:- Egg, small larva, medium larva, large larva, pupa, pre-emergence adult and adult. In order to ensure that each developmental stage was used in the tests, the following procedure was followed:-

Six, 100kg batches of English wheat were winnowed and sieved to remove loose husks and dust and then placed in cold storage at -10° C for 14 days to kill any indigenous mite or insect pests. The grain was then placed in a constant temperature and humidity room (CTH) running at 25° C and 70% relative humidity (rh) for a further 14 days to equilibrate. After the grain had been left to equilibrate, approximately 35,000 unsexed adult *S. granarius* 2 - 4 weeks old, were added to one batch of grain. The insects were removed from the grain after 7 days by sieving it twice over a 2.0 mm aperture sieve, 400 mm wide and 1000 mm long, fitted into an inclined plane sieving machine. Dead insects were removed, and a further 1000 unsexed adult insects 2 - 4 weeks old, were added to the main bulk of the insects to make up the numbers. The grain was then returned to the CTH room for incubation, and the insects were added to the next batch of wheat. The whole process was repeated until all 6 batches had been infested. One week after the insects had been removed from the last batch of grain, the grain was treated. Therefore, each batch should have contained different developmental stages of *S. granarius*.

Each of the six, 100kg batches of grain was then divided into five, 20 kg batches. Four of these were treated with one or other of the pesticides and the fifth was treated with water only to act as a control. Details of the application rate of the pesticides are given in Table 2. The doses used were selected because previous, unpublished work had suggested that, at these doses, some survival of the insects was likely and thus a measurable result could be obtained from each pesticide for comparison.

The pesticides were applied as water-based sprays diluted from commercial formulations, and were applied to the grain by directing the discharge from a hand-held spraygun onto the surface of the grain as it was being tumbled in a concrete mixer. The grain was tumbled for a further five minutes after treatment to aid thorough mixing before samples of approximately 50 g were removed for analysis of the pesticide residues. The treated and control grain was then placed in plastic tanks and returned to the CTH room for incubation. The incubation periods used are shown in Table 1.

After incubation, each batch of grain was sieved twice over a 2.0 mm aperture sieve to remove the insects. The insects were placed onto untreated grain for a period of one week, before being classified as live or dead. Where only small numbers of insects were present, it was possible to count them. However, where the numbers were large, the result was calculated by assessing three batches of 1000 insects and weighing them. The total weight of the bulk of the insects was also recorded and the mean weight of the three batches of 1000 insects was used to calculate the total number of insects.

2. Rice experiment

All tests were carried out using brown rice grown in the USA. The rice, which had a moisture content of about 13.5 - 14.0%, was stored at -10° C for two weeks to kill any infestation before use.

Twenty-five kg batches of rice were treated with methacrifos emulsifiable concentrate using the method described above with intended doses of 4.5 or 9 mg/kg. After application of the pesticide, the treated rice, together with untreated control rice, was stored at 25° C in open-topped bins. Samples were removed with a scoop from the bins at intervals of 0, 1, 2 and 4 weeks, and then at 4-weekly intervals up to 24 weeks after treatment.

Three, replicate 50g lots from each sample were bioassayed with 25 adult *S. oryzae*. The insects, which were 2 - 3 weeks old and came from laboratory cultures, had a known level of resistance to several organophosphate pesticides. The weevils were exposed to the rice at 25° C and 70% r.h. for 7 days, after which the insects were removed from the rice and categorised as being live or dead.

Table 1. The distribution of immature stages of *S. granarius* in the 6 batches of wheat and the time that each batch was incubated before and after treatment.

Batch no.	Stages present	Incubation period (weeks) Pre-treatment	Post-treatment
1	Pre-emergence adults and pupae	6	4
2	Pupae and large larvae	5	5
3	Large and medium larvae	4	6
4	Medium larvae	3	7
5	Small and medium larvae	2	8
6	Small larvae and eggs	1	9

Table 2. The intended dose of each pesticide on the wheat and the residues detected immediately after treatment and after incubation.

Pesticide	Dose mg/kg Intended	Detected after 0 weeks	Detected after incubation#
Chlorpyrifos-methyl	2.3	1.5	1.3
Etrimfos	2.1	2.0	1.6
Methacrifos	2.3	2.2	0.7
Pirimiphos-methyl	2.0	1.9	1.5

Mean values from all 6 batches giving a range of incubation of between 4 and 9 weeks at 25° C.

After the insects had been removed, the rice was incubated for a further 6 weeks before being re-examined to check for progeny. Controls were set up and assessed in the same manner using untreated rice.

The residues of methacrifos in the samples were determined by analysing a 25g sub-sample using the Panel Method (Anon. 1980).

RESULTS

1. Wheat experiment

Each batch contained different developmental stages of *S. granarius* and so was incubated for a different period of time after treatment to ensure that any live insects emerged as adults. Therefore, the level of residue in the batches incubated longest (a difference of 4 to 9 weeks) might be expected to be lowest. In practice, no significant difference was noted between batches and the variation was within that likely to result from sampling error. The results of the chemical analysis are given in Table 2 as means of the 6 batches.

The total numbers of adult insects emerging from all 6 batches of grain are given as totals for each pesticide in Fig. 1. The numbers from each batch and the percentage that were dead are given in Table 3. Between about 43,000 and 12,000 insects emerged from the control batches, with the lowest level of emergence from Batch 6. Ninety-eight percent or more of the control insects were alive. The total number of insects emerging from the treated batches were always less than for the control but there was a considerable variation between the pesticides. Pirimiphos-methyl gave the least control of emergence, whilst methacrifos gave the best. There was also much variation in the percentage of the emerged insects from the treated grain that were alive. In general, more of the insects that emerged from grain treated with methacrifos and chlorpyrifos-methyl were dead than for the other two pesticides.

2. Rice experiment

The levels of methacrifos residues found in samples removed at intervals during the trial are shown in Fig. 2. The doses achieved at the start of the trial were close to those intended but the residues declined with time to about 35% of the original value after 24 weeks.

The results of the mortality counts and the numbers of progeny produced are shown in Table 4. Complete mortality of the adult insects was obtained for 16 weeks at the dose of 9mg/kg and better than 95% mortality was obtained for 4 weeks at 4.5mg/kg. Almost total suppression of progeny was obtained up to 20 weeks and 12 weeks for the higher and lower doses respectively. The results for progeny production from the 8-week sample were,

Figure 1. The mean number of insects emerging from the treated and control grain (mean of six batches)

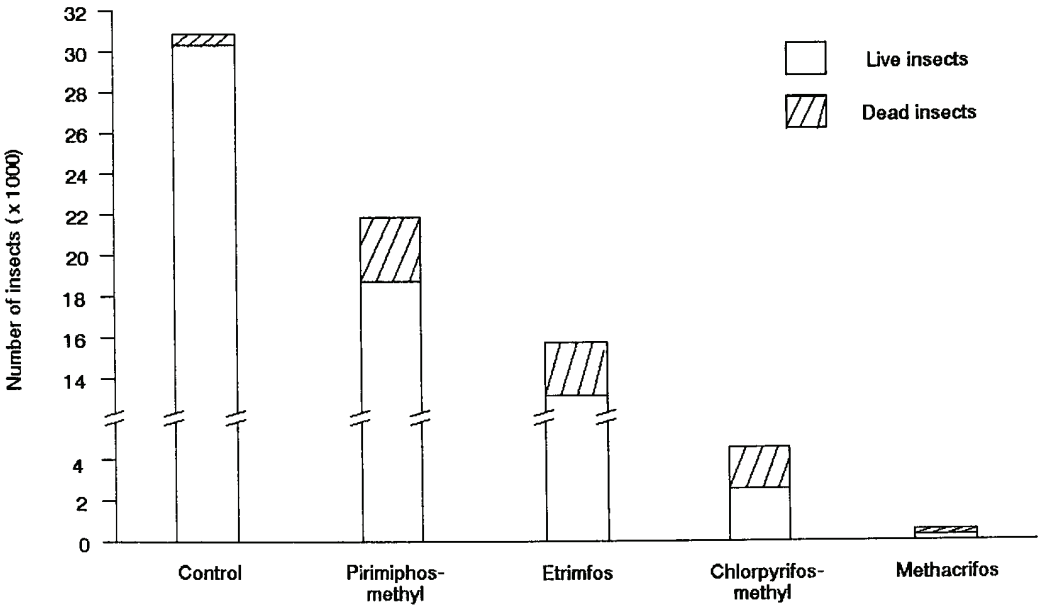

Figure 2. Residues of methacrifos in rice stored at 25 C

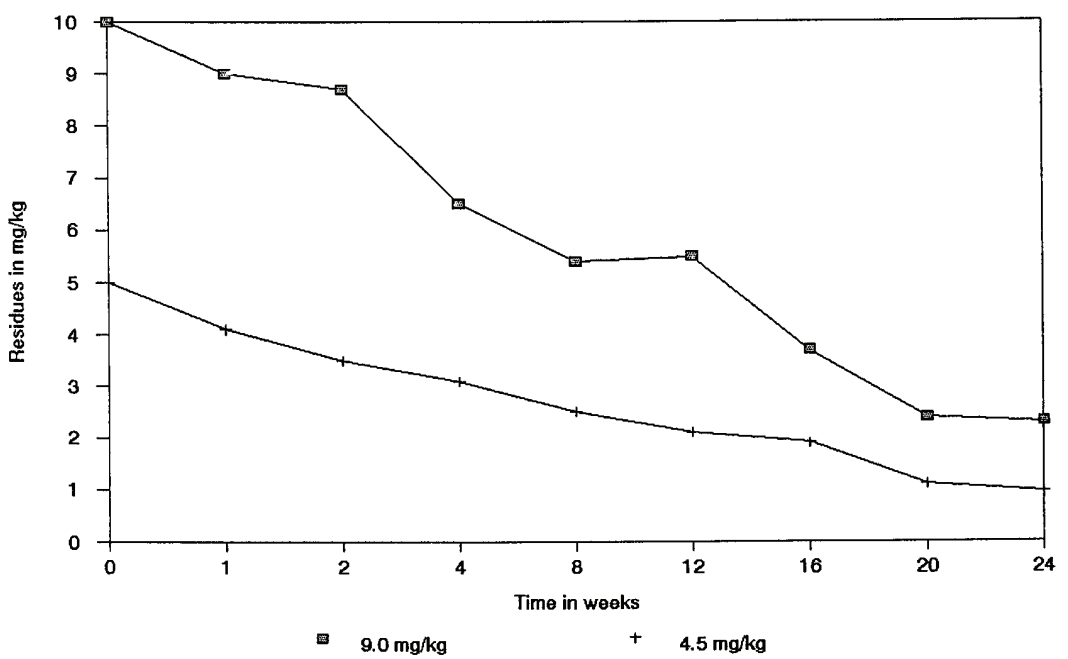

Table 3. The total number and per cent mortality of *Sitophilus granarius* emerging from the batches of treated and control wheat.

Pesticide		Chlorp	Etrim	Methac	Pirim	Control
Batch						
1	Total	1648	3927	112	24312	35233
	% Dead	70.3	30.4	71.3	12.7	0.9
2	Total	4188	17234	50	23454	31882
	% Dead	54.3	14.3	85.3	14.4	0.9
3	Total	6218	22255	157	24341	35391
	% Dead	40.7	8.0	64.7	6.6	1.2
4	Total	8074	26821	109	28760	43361
	% Dead	41.2	20.0	53.2	16.3	1.0
5	Total	6160	15034	504	17881	26265
	% Dead	30.0	6.6	18.5	10.9	2.0
6	Total	3286	3755	294	10999	11776
	% Dead	39.2	18.7	31.8	18.9	2.2

Table 4. The percentage mortality of adult *Sitophilus oryzae* exposed to rice treated with methacrifos and the subsequent numbers of emerging progeny.

Dose mg/kg		Period after treatment in weeks 1	2	4	8	12	16	20	24
4.5	Kill	100	99	99	80	59	25	9	5
	Progeny	0	0	1	-	59	136	205	323
9.0	Kill	100	100	100	100	100	100	69	49
	Progeny	0	0	0	-	0	1	36	94
0.0	Kill	3	0	1	0	1	0	0	0
	Progeny	250	289	269	-	213	364	336	204

unfortunately, lost.

DISCUSSION

The trials on wheat show that there are marked differences in the effectiveness of different pesticides in controlling immature stages of *S. granarius*. Other published data (Thomas *et al*, 1987; Tigar and Pinniger, 1989) suggest that these differences are not related to the ability of the pesticides to kill the adult stages. Methacrifos was the most effective in preventing emergence and, in comparison to the control, only an insignificant number of insects were produced from the treated grain. Coulon, *et al* (1979) showed that methacrifos was very effective in controlling immature *S. granarius*, but only used one pesticide, chlorpyrifos-methyl, for comparison and did not test a wide range of developmental stages.

The differences in emergence between the batches containing different developmental stages were, in general, not sufficiently marked to support firm conlusions. However, the percentage of the emerged adults that were alive tended to increase in the batches that were likely to have contained the most small larvae and eggs. It is possible that for these batches, the insects would spend the greatest length of time deep within the grain feeding on the endosperm, thus allowing the pesticide that was applied to the surface to decay or disperse before the adults emerged.

The efficacy of methacrifos in comparison to the other chemicals would suggest that this chemical was either more active against one or more of the immature stages or that it penetrated into the endosperm in sufficient quantities to kill the insects. This effectiveness was achieved despite methacrifos appearing to have the most rapid rate of decay or loss of the pesticides tested, which would suggest that the chemical was penetrating rapidly into the grain and killing the immature stages, rather than killing the adults just prior to emergence. If this is the case, it further enhances the value of this compound in the control of weevils, as the insects would be killed at an early stage of their development, thus minimising damage.

Using more conventional methods of assessment, good control of another economically important weevil, *S. oryzae*, was obtained on rice. Methacrifos applied at 9 mg/kg to brown rice, gave good control of adults of this strain having some resistance to a range of organophosphate pesticides. Excellent suppression of progeny was obtained for 20 weeks, despite storage of the rice at a temperature likely to encourage rapid decay of residues. The dose of 4.5 mg/kg gave good control initially but its efficacy reduced with time. The markedly different doses needed on rice and wheat in order to obtain good control is a result of the different size of seeds and their different surface area to volume ratios. Rice grains have about 2.5 times the surface area

per unit mass compared with the English wheat used in these trials. Therefore, the pesticide applied to the outer surface of the rice grains, would have been spread over a much larger area compared to the wheat.

Methacrifos has been shown to have great potential for controlling infestations of weevils attacking grains. A single treatment with this compound could be expected to give at least 16 weeks protection, although this would depend on the dose applied and the conditions of storage. In some circumstances, particularly where low terminal residues were desirable, the apparent decay of the compound after application to grains could be an advantage.

This work forms part of a development project on the use of methacrifos to protect stored grain carried out with the support of Ciba-Geigy. Other aspects of the work have been (Price, *et al*, In Press) or will be reported separately.

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EVALUATION DU METHACRIFOS COMME INSECTICIDE DES CEREALES STOCKEES

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RESUME

Le méthacrifos, insecticide organophosphoré, a été étudié sur un éventail de ravageurs des denrées stockées, sur blé, orge et riz. Dans les études en laboratoire, une dose arbitraire de 4,5 mg/kg appliquée sur du blé a donné une bonne efficacité initiale de souches résistantes d'*Oryzeaphilus surinamensis*, *Tribolium castaneum* et *Sitophilus granarius*, mais l'efficacité a diminué après un stockage de 4 semaines. Une dose de 4,75 mg/kg appliquée à du riz a donné une bonne efficacité sur *S. orysae* pendant une période de 20 semaines. Un essai en grandeur réelle a aussi été réalisé en traitant de l'orge dans une malterie. Le grain était fortement infesté par *Oryzeaphilus surinamensis* et les insectes sont morts en 24 heures avec une dose de méthacrifos d'environ 4,75 mg/kg. Des études biologiques sur des échantillons d'orge traitée ont confirmé l'action d'un tel traitement.

Le résultat de ces études montre que le méthacrifos est un insecticide du grain efficace. Il assure une désinsectisation rapide et une protection sur plusieurs semaines, sans mener à des taux de résidus finaux importants.