Pirimiphos Methyl: Effect on Populations of *Tribolium confusum* and *T. castaneum*[1] in Wheat[2,3]

DELMON W. LAHUE[4,5]

U.S. Grain Marketing Research Center, ARS, USDA, 1515 College Avenue, Manhattan, KS 66502

ABSTRACT

Pirimiphos methyl at a rate of 7.8 ppm was more effective than malathion at a rate of 10.4 ppm as a protectant on hard winter wheat against the confused flour beetle, *Tribolium confusum* Jacquelin duVal, and the red flour beetle, *T. castaneum* (Herbst), in a 12-month 0.14 m^3 small bin storage study. Malathion degraded to 16.3% of the initial deposit during the 12-month period but pirimiphos methyl residue degraded more slowly as 83.1% of the initial residue remained on the wheat at 12 months post-treatment.

Toxicity studies showed that the residues of pirimiphos methyl on wheat were very effective against both species of *Tribolium*.

Adult confused flour beetles, *Tribolium confusum* Jacquelin duVal, are usually more tolerant of the killing action of grain protectants than are the red flour beetles, *T. castaneum* (Herbst), but many strains of the red flour beetle are becoming resistant to the killing action of malathion, the most commonly recommended grain protectant and residual insecticide (Champ and Campbell-Brown 1970, Speirs et al. 1967). It was encouraging when Zettler (1974) reported that 5 malathion-resistant strains of the Indian meal moth, *Plodia interpunctella* (Hübner), showed no cross resistance to pirimiphos methyl and concluded that it was a potential replacement for malathion. Subsequently preliminary residual studies with spray applications of 807 and 1076 mg/m^2 AI on wood panels showed that pirimiphos methyl was very effective against adult red and confused flour beetles. Likewise, after 3 months, a few adult flour beetles survived exposure to grain treated with 5 ppm; although no progeny developed, all adults were killed with an application of 10 ppm (LaHue 1975). In other larger-scale studies, we found that all adult confused flour beetles were controlled for 12 months by an application of 8 ppm AI, and only 6 ppm were required to control the red flour beetle populations. We report here the results when this organic phosphorus compound with its relatively low mammalian toxicity (LD_{50} to rats of ca. 2050 mg/kg) was tested as a grain protectant in small 0.14m^3 bin tests.

MATERIALS AND METHODS.—Hard red winter wheat, purchased locally at harvest, was stored in bulk in a metal bin for 8 months. Then the wheat was cleaned with a Clipper® cleaner to remove foreign material and cracked kernels and to improve uniformity in kernel size. The moisture content averaged ca. 12.3%.

Malathion was used as the standard treatment for comparison. It was applied as a water emulsion spray prepared from premium grade 57% malathion EC 0.6 kg AI/liter (5 lb/gal) for a dose of 473 ml concentrate/27.3 metric tons (10.42 ppm). Pirimiphos methyl EC 0.5 kg AI/liter (4.17 lb/gal) was applied at the rate of 7.8 ppm. The emulsions were applied with a ULV atomizing spray assembly (LaHue 1969) modified by the addition of high volume fluid and air nozzles to deliver 18.9 liters (5 gal) finished spray/27.3 metric tons or 0.69 liters/metric ton.

The emulsions were applied to 54.4 kg (2-bu) lots of wheat in a 208.2-liter (55 gal) steel barrel as it rolled at 16 rpm for 10 min on an electric barrel roller. Immediately after 2 lots were treated, the 108.8 kg (4 bu) of treated wheat were placed in 0.14 m^3 (5 ft^3) uncovered fiber drums (small bins) for storage at ca. 26°C and 60% RH for 12 months. Grain surfaces were leveled at 5 cm below the top so each bin had an equal grain surface area available for insect entry. There were 4 replications of each treatment and 4 (check) untreated bins.

Samples were taken for determinations of residue, moisture content of wheat, and insect populations by probing with a nonpartitioned grain trier (probe) at 3-month intervals.

About 3200 each of *T. confusum* and *T. castaneum* adults from laboratory colonies were released in the storage area of each of the following times after the treatment: 15, 40, 70, 135, 190, 230, 280, and 315 days.

At the termination of the test, four 3000 g samples were taken from each bin for a study of the levels of insect infestation. First the live and dead insects were removed from the samples of wheat. Then the samples plus all dusts and siftings containing eggs and larvae were retained for 70 days so we could determine the emergence of developing *Tribolium* infestations. In addition, no-choice bioassays were made by placing ca. fifty 14-, to 28-day-old confused or red flour beetles, with 250-g subsamples plus ca. 1% of finely ground samples in 473-ml glass jars. Then the jars were covered with screened lids. Live and dead insects were removed and counted 21 days later. All

[1] Coleoptera: Tenebrionidae.

[2] Received for publication Sept. 7, 1976.

[3] This paper reports the results of research only; mention of a pesticide does not constitute a recommendation for use by the USDA nor does it imply registration under FIFRA as amended. Also, mention of a commercial or a proprietary product does not constitute an endorsement by the USDA.

[4] Research Entomologist.

[5] The author acknowledges the assistance of Edwin Dicke, Agric. Res. Technician, Loren Davidson, Physical Sci. Technician, and Imogene Davis, Laboratory Aid, in conducting this study.

screenings and dusts were returned to the respective jars and were held 56 days for red flour beetle and 63 days for confused flour beetle F_1 progeny emergence. After progeny counts, all jars were retained for 120 days longer so a visual assessment could be made of damage by the progeny.

Moisture determinations were made with a Steinlite® RCT-B moisture tester. The primary method of the analysis for residues was adapted from Storrherr et al. (1964). Residues of pirimiphos methyl were extracted from the wheat and were cleaned for analysis with a Tracor® MT-200 gas chromatograph as follows: 25 g of finely ground wheat were homogenized at high speed with 75 ml of acetonitrile saturated with hexane for 5 min in a Sorvall® homogenizer. The supernatant fluid was filtered through a plug of glass wool. Then 6 ml of the filtrate was cleaned by filtering through 2 g of an adsorbent mixture (5 g Norit® SG-1, 4 g MgO powder and 8 g Celite® 545) in a glass tube (10 mm ID × 250 mm long) with drawn tip. Both ends of the tube had been plugged with glass wool. The residue was eluted from the column with 25 ml of 25% ethyl acetate in benzene (vol/vol) and the filtrate was collected in a round bottom, long-necked boiling flask that had a 24/40 T joint. The flask was placed on a rotary evaporator, and the contents were evaporated just to dryness in a 37°C water bath. The residue was picked up in 6 ml of *n*-hexane. An aliquot of this extract was injected into the gas chromatograph.

Residues were determined by GLC at the following conditions: column—6.4 mm OD, 4 mm ID × 112 cm long PYREX® packed with 3% OV-1 on Chromasorb® W (100–120 mesh). AW-DMCS: column temperature 190°C; injection temperature—150°C; detector temperature—210°C; carrier gas—60 ml N_2/min; H_2—180 ml/min; air—30 ml/min; O_2—30 ml/min; electrometer—input attenuator 10^5—output attenuator 32 (3.2×10^{-7} AFS) depending on the sensitivity desired. Retention time of pirimiphos methyl was 85 sec. All peak areas were integrated with an Infotronics® Integrator.

RESULTS AND DISCUSSION.—Moisture content of treated wheat dropped from ca. 12.3 to 11.8% during the 12-month period but that of the untreated and heavily infested check wheat remained near the initial content of 12.3%.

Residues in ppm were as follows:

Storage period	Malathion	Pirimiphos methyl
Dose applied	10.4	7.8
24 h	8.6	6.5
1 month	5.2	6.1
3 month	3.8	5.6
6 month	3.0	6.2
9 month	2.0	5.9
12 month	1.4	5.4

Thus in 12 months, malathion residue degraded gradually until only 16.3% of the initial deposit remained; pirimiphos methyl residue degraded only slightly as 83.1% of initial deposit remained.

The live *Tribolium* spp. adults that were recovered from the 3000-g samples of wheat taken from each bin at the specified intervals provided an indication of the active populations within the grain mass in the bins throughout the storage period (Table 1). In the untreated check bins, populations of both species increased gradually during the storage period. In the bins treated with malathion, populations of *T. confusum* were larger than populations of *T. castaneum*. Wheat treated with pirimiphos methyl was well protected against infestations by either species.

The average numbers of *Tribolium* spp. that emerged during the 70-day period, after all live and dead insects were removed from the 3000-g samples taken from each bin at the end of the study, were as follows:

Treatment	*T. confusum*	*T. castaneum*
Malathion	87.8	29.0
Pirimiphos methyl	11.1	3.7
Check (untreated)	89.2	97.3

Moreover, there were no significant differences in samples taken from the various bins.

Table 1.—Live adult flour beetles recovered from wheat during 12 months' storage.

Sampling period (months)	Avg no. of beetles per 3000 g sample[a]					
	Untreated check		Malathion		Pirimiphos methyl	
	T. confusum	*T. castaneum*	*T. confusum*	*T. castaneum*	*T. confusum*	*T. castaneum*
3	42.2	40.3	1.0	0.0	2.1	0.0
6	131.0	146.7	11.5	3.2	2.3	.2
9	159.0	176.4	47.8	16.0	4.7	1.0
12	190.3	239.5	100.0	32.0	1.3	1.1

[a] Four replicates/treatment.

Toxicity studies conducted at 3, 6, 9, and 12 months posttreatment showed that the residues of pirimiphos methyl on the wheat continued to be very effective against both species of *Tribolium*. All *T. castaneum* adults were killed, and no F_1 progeny was recorded until 12 months posttreatment when 5 adults developed in one sample. At that time, 2 of the 4 replicates of wheat exposed to *T. confusum* contained 16 progeny, 9 in one sample and 7 in the other; untreated check samples averaged 56.2, 64.0, 57.0 and 67.0 progeny/replicate, respectively, for the 4 succeeding sampling periods.

Malathion residue on wheat prevented all production of *T. castaneum* F_1 progeny for ca. 9 months; however, at that time, only 7.0% of the adults were killed. An average of 23.2 F_1 progeny/replicate was recorded after 12 months. Mortalities of adult *T. confusum* in wheat with malathion residues were 73.5, 58.6, 12.3, and 4.5%, respectively, for the 4 successive periods, but only 5.0, 4.0, 7.6, and 13.0 F_1 progeny, respectively, developed to the adult stage.

Visual assessments of damage by both *Tribolium* spp. to samples of wheat exposed 12 months after treatment with pirimiphos methyl showed no damage to the kernels 120 days after mortality readings were made. Pirimiphos methyl is thus a very promising insecticide for control of red and confused flour beetles.

REFERENCES CITED

Champ, B. R., and M. J. Campbell-Brown. 1970. Insecticidal resistance in Australian *Tribolium castaneum* (Herbst) (Coleoptera, Tenebrionidae) J. Stored Prod. Res. 6: 111–31.

LaHue, D. W. 1969. Evaluation of several formulations of malathion as a protectant of grain sorghum against insects . . . In small bins. Market. Res. Rep. No. 828. 19 pp.

1975. Pirimiphos methyl as a short term protectant of grain against stored product insects. J. Econ. Entomol. 68: 235–6.

Speirs, R. D., L. M. Redlinger, and H. P. Boles. 1967. Malathion resistance in the red flour beetle. Ibid. 60: 1373–4.

Storrherr, R. W., M. E. Getz, R. R. Watts, S. J. Friedman, F. Erwin, L. Guilffrida, and F. Ives. 1964. Identification and analyses of five organophosphate pesticides: recoveries from crops fortified at different levels. J. Assoc. Off. Agric. Chem. 47: 1087–93.

Zettler, J. L. 1974. PP511: Toxicity to malathion-resistant strains of the Indian meal moth. J. Econ. Entomol. 67: 450–1.

Reprinted from the
Journal of Economic Entomology