Residual Effectiveness of Emulsion and Encapsulated Formulations of Malathion and Fenitrothion against Four Stored Grain Beetles[1,2]

DELMON W. LAHUE[3] AND AHMED KADOUM[4]

U. S. Grain Marketing Research Laboratory, Federal Research, SEA, USDA, Manhattan, KS 66502

ABSTRACT

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Emulsifiable concentrate and encapsulated formulations of malathion and fenitrothion were applied to plywood surfaces at 135, 269, 538, 807, and 1076 mg AI/m² to determine their toxicity and persistence against the rice weevil, *Sitophilus oryzae* (L.), confused flour beetle *Tribolium confusum* Jacquelin duVal, red flour beetle *T. castaneum* (Herbst), and lesser grain borer *Rhyzopertha dominica* (F.). The insects were exposed to the treated surfaces for 6, 12, 24, 48, and 72 h at 1, 3, 6, 9, and 12 mo posttreatment, and 96 h readings were made 12 mo posttreatment.

In general, fenitrothion was more effective than malathion in comparative tests. Also, the encapsulations were more persistent than the emulsion. *T. confusum* was the most tolerant to the killing action of the residues. Persistence of residues and insecticidal activity were in direct relation to dosage application.

There is wide-spread agreement that the maintenance of reserve food stocks is wise and necessary on a world-wide basis. Pesticides are very important as assurances against the ravages of stored grain insects. Successful control of infestations depends upon the many facets of an integrated pest control system. One such facet is the proper use of residual sprays. Malathion and fenitrothion are used in many parts of the world as protectants against the rice weevil, *Sitophilus oryzae* (L.), red flour beetle, *Tribolium castaneum* (Herbst), confused flour beetle, *T. confusum* Jacquelin duVal, and lesser grain borer, *Rhyzopertha dominica* (F.), as they are relatively low in mammalian toxicity, readily available, and reasonable in cost.

In this study, we compared the effectiveness of sprays prepared from emulsifiable concentrates and encapsulated formulations of malathion and fenitrothion applied to plywood panels as residual toxicants to the aforementioned insects.

Materials and Methods

Malathion EC (599.2 g AI/liter), encapsulated malathion (210 AI/liter), fenitrothion EC (958.7 g/liter), and encapsulated fenitrothion (317.6 g/liter) were each diluted with neutral distilled water for applications to 61×61 cm² (3721 cm²) plywood panels. A ULV spray assembly (LaHue 1969) modified by the substitution of high volume fluid and flat pattern air nozzles was used to apply one liter finished spray/9.3 m² surface area. The panels were cut into four 30.4 cm² after the desired aging of the residues.

Four panels (replicates) were sprayed with each dosage, and additional panels were sprayed with distilled water for the control exposures. All uncut panels were stored vertically at 26°±2°C and 55±5% RH in an unlighted room.

Preliminary studies determined the amount of liquid needed to give a spray application to the plywood panels that approached liquid run-off. Also, other studies were made with malathion emulsion and encapsulation applications to glass and galvanized sheet metal surfaces to determine the loss due to drift and splattering. These panels were washed with acetonitrile saturated with hexane after a 3-h drying period to provide recovery data to estimate the actual insecticidal deposits. Also, paper panels were sprayed and then prepared for residue analysis. The method used for these analyses was adapted from Storrherr et al. (1964).

Insects were exposed to the treated plywood squares for 6, 12, 24, 48, and 72 h at 3, 6. 9, and 12 mo posttreatment by confining 50 adults (10–16 days old) of a species to the surface with a plastic ring, 9 cm diam and 1.5 cm high. The insides of each ring were coated with fluon or teflon to prevent the insects from climbing the sides. The rings with rice weevils, red flour beetles, and lesser grain borers were covered on the top with a 20×20 mesh screen to prevent loss by flight. All exposures were made at 24°±2°C and 60±8% RH. After exposures, insects were separated into 2 lots, those appearing moribund and dead and those that were apparently healthy unaffected adults. Then, they were retained for 96 h for a final assessment of mortality. Rice weevils and lesser grain borers were retained on wheat kernels; red and confused flour beetles were retained on a 50–50 mixture of whole wheat flour and corn meal.

Readings also were made after 96 h of exposure at 12 mo posttreatment.

Results and Discussion

Studies with application of water sprays to galvanized sheet metal and glass showed considerable run-off of the liquid required to give adequate coverage to the more absorbent paper and plywood panels; consequently, metal and glass panels were sprayed in a horizontal position for the preliminary residue work. These initial studies also showed that 107.6 ml of finished spray/m² (ca. 2.64 gal/1000 ft²) were required to give a spray covering to a vertical plywood surface which approached run-off.

The avg malathion residue deposits recovered 3 h

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[2] 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.

[3] Deceased.

[4] Research entomologist, Dept. of Entomology, Kans. Agric. Exp. Stn., Kansas State University, Manhattan, KS 66506.

Table 1.—Mortality of adult insects exposed to plywood surfaces 6 mo after treatments with malathion.

Formulation and dose (mg/m²)	Avg % mortality after indicated hours of exposure				
	6	12	24	48	72
Emulsion			Rice weevils		
269	80.8	100.0	100.0		
135	0	50.2	75.0	98.0	100.0
			Red flour beetles		
269	64.0	70.1	100.0	100.0	
135	8.5	50.2	89.3	100.0	100.0
			Confused flour beetles		
538	98.0	100.0	100.0		
269	48.0	88.5	100.0	100.0	
135	0.0	12.0	40.4	96.3	98.7
			Lesser grain borer		
1076	73.8	91.2	100.0	100.0	
807	50.0	73.1	98.6	100.0	100.0
538	8.6	62.5	95.0	100.0	100.0
269	3.9	38.0	85.3	100.0	100.0
135	2.0	10.0	56.0	88.6	94.0
Encapsulations			Rice weevils		
296	96.2	100.0	100.0		
135	21.1	63.6	89.4	100.0	100.0
			Red flour beetles		
135	37.9	94.9	100.0	100.0	
			Confused flour beetles		
135	8.0	74.8	100.0	100.0	
			Lesser grain borer		
1076	75.0	100.0	100.0		
807	66.7	100.0	100.0		
538	29.0	93.3	100.0	100.0	
269	19.2	78.8	98.0	100.0	100.0
135	7.4	33.3	66.7	100.0	100.0

Table 2.—Mortality of adult insects exposed to plywood surfaces 9 mo after treatments with malathion.

Formulation and dose (mg/m²)	Avg % mortality after indicated hours of exposure			
	12	24	48	72
Emulsion		Rice weevils		
1076	17.2	79.6	100.0	100.0
807	15.0	32.9	96.8	100.0
538	3.3	11.1	78.9	100.0
269	0.0	7.8	30.6	96.8
135	0.0	0.0	7.8	16.7
		Red flour beetles		
1076	50.0	100.0	100.0	
807	27.9	80.8	100.0	100.0
538	19.2	65.0	98.0	100.0
269	0.0	43.3	90.0	100.0
135	0.0	0.0	3.7	26.1
		Confused flour beetles		
1076	24.1	79.3	100.0	100.0
807	10.0	32.2	81.5	100.0
538	8.0	28.0	88.0	100.0
269	0.0	3.8	14.8	46.4
135	0.0	0.0	3.7	16.7
		Lesser grain borer		
1076	27.2	41.0	82.8	100.0
807	17.4	22.2	77.7	89.9
538	7.9	17.9	67.9	85.7
269	0.0	2.2	48.7	80.8
135	0.0	0.0	17.9	66.7
Encapsulation		Rice weevils		
1076	61.5	100.0	100.0	
807	25.9	67.7	100.0	100.0
538	10.0	46.8	68.7	100.0
269	0.0	10.0	38.8	100.0
135	0.0	0.0	11.1	19.2
		Red flour beetles		
1076	100.0	100.0		
807	84.0	100.0	100.0	
538	7.7	53.6	100.0	100.0
269	0.0	38.8	75.0	100.0
135	0.0	0.0	3.7	33.8
		Confused flour beetles		
1076	59.3	88.9	100.0	100.0
807	18.5	70.4	100.0	100.0
538	0.0	17.2	48.3	82.7
269	0.0	0.0	11.1	75.1
		Lesser grain borer		
1076	59.6	100.0	100.0	
807	31.0	79.3	90.1	100.0
538	3.8	27.7	77.8	100.0
269	0.0	0.0	56.9	100.0
135	0.0	0.0	40.2	80.2

after application of the intended doses in one liter of finished emulsion spray/9.3 m² and their SD's were 89.8±1.4, 91.9±1.7, and 96.8±0.7 for galvanized metal, glass, and paper, respectively. Three separate replicated applications also were made from the encapsulation spray; avg recoveries and their SD's were 91.6±1.6, 93.2±1.1, and 98.1±0.3 for galvanized metal, glass, and paper, respectively. However, complete recoveries were obtained from plywood in both emulsions and encapsulation sprays.

The amount of loss due to drift and splattering was greatest on the galvanized sheet metal and glass panels, but the absorbent panels retained most of the residue. Analyses of the source emulsions and encapsulations showed averages of 98.8 and 97.1% of the calculated A-I concentrations, respectively, to be present in the finished sprays.

Tables 1–3 give mortality data for the 6, 9, and 12-mo exposures to residues of the malathion formulations. Data are not listed when 100% mortality occurred with the 6-h exposure; however, encapsulations were consistently more effective than the emulsion applications. The 1076 and 807 rates of the malathion encapsulation killed 55.6 and 36.0, and 46.3 and 18.5% of the red flour beetles during the 9- and 12-mo exposures, respectively.

Differences in the persistence and effectiveness of each formulation depended on the applied dose, length of exposure period, and differential susceptibility of the species tested. Complete mortality of rice weevils and red flour beetles was obtained at all doses of the 4 formulations at 1 and 3 mo with 12-h exposures to treated surfaces; however, averages of only 29.2 and 17.1 and 47.3 and 36.9% mortality of the confused flour beetles were recorded for the emulsion and encapsulation applications, respectively, with the 135 mg dose at 1 and 3 mo posttreatment. The lesser grain borers were consid-

Table 3.—Mortality of adult insects exposed to plywood surfaces 12 mo after treatments with malathion.

Formulation and dose (mg/m²)	Avg % mortality after indicated hours of exposure				
	12	24	48	72	96
Emulsion			Rice weevils		
1076	0.0	18.9	54.7	86.8	100.0
807	0.0	5.6	13.0	33.3	92.6
538	0.0	0.0	5.8	19.6	78.4
269	0.0	0.0	0.0	15.1	57.3
135	0.0	0.0	0.0	4.0	20.0
			Red flour beetles		
1076	0.0	10.2	23.7	33.9	50.8
807	0.0	0.0	0.0	9.1	35.7
538	0.0	0.0	0.0	3.6	16.4
269	0.0	0.0	0.0	1.8	4.0
135	0.0	0.0	0.0	1.8	1.8
			Confused flour beetles		
1076	0.0	0.0	0.0	32.1	56.6
807	0.0	0.0	0.0	3.5	7.0
538	0.0	0.0	0.0	0.0	4.0
269	0.0	0.0	0.0	0.0	0.0
135	0.0	0.0	0.0	0.0	0.0
			Lesser grain borer		
1076	0.0	5.5	12.7	21.4	43.2
807	0.0	7.3	15.3	21.7	37.6
538	0.0	0.0	15.0	19.4	21.3
269	0.0	0.0	0.0	2.3	3.7
135	0.0	0.0	0.0	0.0	0.0
Encapsulation			Rice weevils		
1076	57.7	94.2	100.0	100.0	
807	7.7	60.4	96.0	100.0	100.0
538	4.0	38.0	72.6	90.0	100.0
269	0.0	17.6	28.4	76.6	100.0
135	0.0	0.0	17.2	29.0	82.8
			Red flour beetles		
1076	89.4	96.5	100.0	100.0	
807	58.9	89.3	100.0	100.0	
538	15.3	58.1	96.4	100.0	100.0
269	0.0	3.7	48.1	98.0	100.0
135	0.0	0.0	4.1	29.6	32.0
			Confused flour beetles		
1076	49.3	72.2	90.6	100.0	100.0
807	11.1	50.3	67.4	71.8	82.3
538	0.0	3.7	11.1	40.8	51.1
269	0.0	0.0	7.8	26.4	50.0
135	0.0	0.0	0.0	3.7	7.8
			Lesser grain borer		
1076	34.0	84.6	100.0	100.0	
807	11.5	67.8	91.9	100.0	100.0
538	5.8	30.1	70.0	80.0	89.2
269	1.9	3.8	48.1	63.2	71.0
135	0.0	0.0	21.8	24.5	35.2

Table 4.—Mortality of adult insects exposed to plywood surfaces 6 mo after treatment with fenitrothion.

Formulation and dose (mg/m²)	Avg % mortality after indicated hours of exposure				
	6	12	24	48	72
Emulsion			Rice weevils		
269	95.7	100.0	100.0		
135	26.1	70.1	93.9	100.0	100.0
			Red flour beetles		
269	86.5	100.0	100.0		
135	10.0	84.0	96.0	100.0	100.0
			Confused flour beetles		
269	70.0	93.8	100.0	100.0	
135	10.0	20.2	42.7	89.6	98.8
			Lesser grain borer		
1076	81.3	100.0	100.0		
807	70.3	100.0	100.0		
538	61.7	98.5	100.0	100.0	
269	45.2	92.3	98.0	100.0	100.0
135	5.9	11.8	78.8	95.7	98.0
Encapsulation			Rice weevils		
135	45.2	90.6	100.0	100.0	
			Red flour beetles		
135	44.4	96.3	100.0	100.0	
			Confused flour beetles		
269	94.3	100.0	100.0		
135	20.0	90.0	98.0	100.0	100.0
			Lesser grain borer		
1076	86.9	100.0	100.0		
807	78.1	100.0	100.0		
538	60.9	100.0	100.0		
269	30.8	98.2	100.0	100.0	
135	20.7	79.3	98.3	100.0	100.0

erably more tolerant since doses of 1076 and 807 mg/m² of each formulation were required to give 100% mortality with a 12-h exposure or 3 mo posttreatment.

Tables 4–6 show the results obtained with exposures to the fenitrothion residues. The encapsulations were more effective than the emulsions against the 4 test species. Strong and Sbur (1965) and Lemon (1966) reported that topical applications of fenitrothion were more toxic than malathion to red and confused flour beetles. Champ et al. (1969) reported that fenitrothion was more toxic than malathion to both rice weevils and lesser grain borers. In our studies, fenitrothion residue was generally more effective than malathion residue; however, after 12 mo of aging, the malathion residues remaining from the encapsulation applications were nearly as effective as residues from the fenitrothion treatments. When exposed for 6 h at 12 mo posttreatment, 67.9 and 53.9% of the red and confused flour beetles, respectively, were killed by residues from the 1076 mg/m² doses of fenitrothion encapsulations; however, no mortalities occurred as a result of exposures to residues from the emulsion application with this exposure.

The speed of action of fenitrothion against all species used was accelerated by increased dosage rates. Also, effectiveness of the lower doses declined more rapidly than that of the higher doses. The general order of tolerance to the residues on the panels for all formulations was (1) lesser grain borers, (2) confused flour beetles, (3) red flour beetles, and (4) the rice weevils. Under practical field conditions, insects need to be killed with short exposures to toxic residues of an insecticide. Otherwise, they can survive and move away to infest and oviposit in the stored grain or grain products.

Table 5.—Mortality of adult insects exposed to plywood surfaces 9 mo after treatment with fenitrothion.

Formulation and dose (mg/m²)	Avg % mortality after indicated hours of exposure: 6	12	24	48	72
Emulsion			Rice weevils		
1076	00.0	17.4	82.6	100.0	100.0
807	00.0	3.7	61.5	100.0	100.0
538	00.0	0.0	43.1	100.0	100.0
269	00.0	0.0	32.0	89.8	100.0
135	00.0	0.0	0.0	11.1	50.2
			Red flour beetles		
1076	18.5	100.0	100.0		
807	8.5	96.3	100.0	100.0	
538	00.0	71.8	100.0	100.0	
269	00.0	25.0	41.7	100.0	100.0
135	00.0	0.0	3.8	42.3	71.4
			Confused flour beetles		
1076	00.0	66.7	84.1	100.0	
807	00.0	28.0	68.0	92.9	100.0
538	00.0	11.5	46.2	77.3	100.0
269	00.0	0.0	11.1	25.9	62.9
135	00.0	0.0	0.0	11.1	19.1
			Lesser grain borer		
1076	00.0	55.2	73.6	100.0	
807	00.0	50.0	66.7	100.0	
538	00.0	17.1	37.2	89.9	100.0
269	00.0	3.7	27.6	68.2	96.2
135	00.0	0.0	3.7	33.3	67.7
Encapsulation			Rice weevils		
1076	44.1	93.6	100.0	100.0	
807	33.0	80.2	92.6	100.0	100.0
538	7.1	37.3	80.0	100.0	100.0
269	00.0	0.0	43.0	96.4	100.0
135	00.0	0.0	11.5	50.1	100.0
			Red flour beetles		
1076	100.0	100.0			
807	100.0	100.0			
538	78.7	100.0	100.0		
269	61.5	76.9	100.0	100.0	
135	38.5	62.5	100.0	100.0	
			Confused flour beetles		
1076	100.0	100.0			
807	90.0	100.0	100.0		
538	26.9	61.3	93.5	100.0	100.0
269	00.0	50.4	77.8	100.0	100.0
135	00.0	7.6	30.8	80.2	93.4
			Lesser grain borer		
1076	10.0	88.5	100.0	100.0	
807	00.0	77.8	100.0	100.0	
538	00.0	51.9	78.8	100.0	100.0
269	00.0	38.5	70.8	100.0	100.0
135	00.0	11.5	51.5	83.3	100.0

Table 6.—Mortality of adult insects exposed to plywood surfaces 12 mo after treatment with fenitrothion.

Formulation and dose (mg/m²)	Avg % mortality after indicated hours of exposure: 12	24	48	72	96
Emulsion			Rice weevils		
1076	00.0	14.8	78.1	100.0	100.0
807	00.0	3.7	38.9	96.3	100.0
538	00.0	0.0	11.1	32.0	82.0
269	00.0	0.0	0.0	30.9	68.4
135	00.0	0.0	0.0	13.2	30.2
			Red flour beetles		
1076	1.8	17.9	98.6	100.0	100.0
807	00.0	1.9	40.7	44.3	53.6
538	00.0	0.0	11.1	14.0	42.0
269	00.0	0.0	1.8	3.6	5.8
135	00.0	0.0	0.0	0.0	1.9
			Confused flour beetles		
1076	00.0	1.9	12.5	46.1	61.4
807	00.0	0.0	0.0	3.7	6.0
538	00.0	0.0	0.0	1.9	3.8
269	00.0	0.0	0.0	0.0	2.0
135	00.0	0.0	0.0	0.0	0.0
			Lesser grain borer		
1076	00.0	24.3	50.0	72.5	81.0
807	00.0	14.3	26.7	51.4	62.0
538	00.0	7.0	19.2	23.2	25.9
269	00.0	0.0	10.2	20.1	23.4
135	00.0	0.0	0.0	0.0	0.0
Encapsulation			Rice weevils		
1076	56.7	94.8	99.4	100.0	100.0
807	41.1	86.1	97.8	100.0	100.0
538	30.3	43.0	86.0	100.0	100.0
269	3.4	37.8	69.4	98.0	100.0
135	00.0	0.0	0.0	23.9	35.3
			Red flour beetles		
1076	100.0	100.0			
807	100.0	100.0			
538	67.9	76.9	97.1	100.0	100.0
269	49.2	61.0	81.3	98.0	100.0
135	27.6	36.3	59.2	68.9	72.0
			Confused flour beetles		
1076	86.3	91.7	95.7	100.0	100.0
807	41.0	52.9	67.7	74.6	89.7
538	11.1	19.8	49.6	62.1	73.4
269	00.0	7.7	24.2	41.0	61.0
135	00.0	0.0	3.8	7.7	11.9
			Lesser grain borer		
1076	56.9	86.3	100.0	100.0	
807	29.7	71.1	93.2	100.0	100.0
538	19.2	37.2	79.1	92.0	96.7
269	3.7	18.6	56.2	71.1	83.0
135	00.0	7.8	26.1	31.7	40.4

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