Gardona as a Protectant Against Insects in Stored Wheat[1]

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ABSTRACT

Gardona® (2-chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate) was tested on hard winter wheat as a protectant against adult rice weevils, *Sitophilus oryzae* (L.); red flour beetles, *Tribolium castaneum* (Herbst); confused flour beetles, *T. confusum* Jacquelin duVal; and lesser grain borers, *Rhyzopertha dominica* (F.). Gardona was applied as an emulsion at dosages of 5, 10, and 20 ppm to wheat containing 10, 12, and 13.5% moisture. Evaluations of results were made at intervals by observing the mortalities after aging of the treated wheat, by counting the number of progeny developing after the toxicity test exposures, and by assessing the damage by progeny to the treated grain. Malathion applied at a rate intended to give a deposit of 10 ppm was used as the basis for comparison.

Gardona at 10 ppm generally was not so effective as malathion, but considerable protection was afforded wheat treated with this insecticide. High moisture content of the wheat lowered the efficacy of Gardona, but the adverse effect of high moisture was compensated for to some extent when the dosage was increased.

In an assessment of the potential of an insecticide for use against stored-grain insects, it is important to take into account the mammalian toxicity. The acute oral toxicity of Gardona® (2-chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate) to rats is very low (4000–5000 mg/kg). Furthermore, the mammalian toxicity of the decay or degradation products should not exceed that of the parent product, and the degradation products must be readily identifiable. Jennings (1970) stated that radio-isotope studies conducted with Gardona in the laboratory and the field show that none of the degradation products are of high mammalian toxicity, and, apart from Gardona and its stero-isomer, that none of the residues are cholinesterase inhibitors. Stabilization of the parent product during shelf storage is essential.

According to Strong (1970) Gardona has potential as a residual insecticide for certain species of stored-product insects. Lemon (1967) found Gardona (SD-8447) to be more effective than malathion with topical applications of 4 dosages in tests with confused flour beetles, *Tribolium confusum* Jacquelin duVal; red flour beetles, *T. castaneum* (Herbst); lesser grain borers, *Rhyzopertha dominica* (F.); cigarette beetles, *Lasioderma serricorne* (F.); drugstore beetles, *Stegobium paniceum* (L.); and maize weevils, *Sitophilus zeamais* Motschulsky. He concluded that Gardona merited further evaluation as a grain protectant and as a residual spray on warehouse surfaces.

Preliminary laboratory studies with Gardona applied at a calculated dosage of 10 ppm to cleaned, uninfested wheat containing 11.80% moisture revealed complete kills of adult rice weevils, *Sitophilus oryzae* (L.) and red flour beetles, and prevented the establishment of infestations from exposures made immediately after treatment and 1 and 3 months later. After 6 months, a slight loss of effectiveness was noted, but the results compared favorably with those obtained in other tests with an application of 10 ppm malathion.

Newly harvested stored wheat is often found to contain 13.5% or more moisture. Strong and Sbur (1960) found 12% moisture content to be the maximum safe level and 14% the critical level for effective protection of wheat by malathion deposits. Watters (1959) found the moisture content of wheat to be an important factor influencing the effectiveness of malathion against the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens). He found also that the adverse effect of high moisture on the effectiveness of malathion could be compensated for, to some extent, by an increase in dosage. Based on the aforementioned findings, tests were undertaken by applying a water emulsion of Gardona to hard winter wheat containing 10.0, 12.0, and 13.5% moisture before treatment.

The objective of the study reported here was to determine the effectiveness of 3 dosages of Gardona applied to wheat to protect it against adult rice weevils, confused flour beetles, red flour beetles, and lesser grain borers during a 12-month storage period.

MATERIALS AND METHODS.—Cleaned, uninfested lots of hard winter wheat, 'Scout' variety, were tempered to the desired moisture levels. The souce lots were held at 26.7 ± 1.1°C for 35 days in covered fiberboard drums lined with 6-mil plastic interliners. All moisture determinations were made on a Steinlite 512 RC moisture tester.

Test insects were reared in a room maintained at 26.7 ± 1.1°C with 60 ± 5% RH. The 14-day-old rice weevils and 7-day-old lesser grain borers used were reared on hard winter wheat, Scout variety, containing 12.5% moisture. The 14-day-old red and confused flour beetles were reared on a nutriment containing 10 parts finely ground wheat, 10 parts finely ground yellow corn, 2 parts oatmeal, 2 parts brewer's yeast, and 1 part glycerine.

Lots of 1000 g of tempered wheat were placed in 3.785-liter, widemouth glass jars. A newly formulated emulsifiable concentrate containing 44.9% Gardona and related compounds (479.36 g tech material/liter) was diluted with neutral distilled water to make emulsions for 1-ml applications to the wheat for deposits of 5, 10, and 20 ppm actual Gardona. The emulsions, which were prepared immediately before use, were kept in constant agitation at 26.7 ± 1.1°C.

Applications were made with a 1-ml volumetric pipette to the inside wall of the 3.785-liter glass jars above the grain level while the jars were turning on a 33-rpm turntable. Immediately after application the jars were shaken by hand for 30 sec and then rotated for 15 min on a mechanical tumbler to mix the Gardona with the grain. Each application was replicated at least 5 times. After the required aging in sealed jars, 250-g samples were removed and placed in 473-ml glass mason

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[4] Mention of a proprietary product does not imply endorsement by the USDA.

Table 1.—Mortality of adult rice weevils and development of F_1 progeny after 21 days' exposure to residues of Gardona and malathion on hard winter wheat.

Aging period, insecticide, and dosage	10.0% moisture wheat			12.0% moisture wheat			13.5% moisture wheat		
		Progeny			Progeny			Progeny	
	Adult mortality	No.[a]	Damage rating[b]	Adult mortality	No.[a]	Damage rating[b]	Adult mortality	No.[a]	Damage rating[b]
3 months									
Gardona									
20 ppm	100	5.3	0	100	43.0	0.3	100	72.0	1.3
10 ppm	100	17.7	0	100	111.1	1.3	89.8	265.0	2.7
5 ppm	100	67.0	1.3	70.6	189.5	2.0	2.5	1206.3	5.0[c]
Malathion									
10 ppm	100	0	0	100	0	0	100	0	0
Untreated	2.2	596.2	3.7	0.6	1098.2	5.0[c]	1.1	1109.0	5.0[c]
6 months									
Gardona									
20 ppm	100	4.0	0	100	27.7	0	100	171.0	1.7
10 ppm	100	11.7	0	91.7	189.4	1.7	35.1	545.3	3.3
5 ppm	97.5	62.3	1.7	54.3	302.0	2.3	6.3	1425.7	5.0[c]
Malathion									
10 ppm	100	0	0	100	4.1	0	100	22.8	1.0
Untreated	1.8	606.0	3.3	2.0	1209.3	5.0[c]	0.8	1287.2	5.0[c]
9 months									
Gardona									
20 ppm	100	21.7	0.3	100	39.4	.7	94.0	396.3	2.7
10 ppm	94.4	65.3	1.3	69.9	319.0	2.3	40.4	927.0	5.0
5 ppm	31.1	520.0	2.3	33.3	641.1	3.0	1.9	1301.7	5.0[c]
Malathion									
10 ppm	100	4.0	0	98.7	11.4	0	90.2	136.2	1.6
Untreated	2.2	701.9	3.7	2.4	1159.6	5.0[c]	.4	1237.4	5.0[c]
12 months									
Gardona									
20 ppm	100	32.0	.3	81.1	139.4	1.7	58.1	626.0	3.3
10 ppm	98.7	79.3	1.3	43.0	491.0	2.7	7.6	1213.2	5.0[c]
5 ppm	12.8	571.3	2.7	16.6	989.3	4.3	1.2	1456.7	5.0[c]
Malathion									
10 ppm	100	20.8	.2	80.8	91.7	1.2	61.0	402.2	3.4
Untreated	2.8	693.0	3.3	2.0	1319.0	5.0[c]	2.4	1379.0	5.0

[a] Progeny counts made 63 days after infestation.
[b] Damage 120 days after infestation ranged from 0 (no visible infestation or damage) to 5 (heavy infestation, damage and grain spoilage).
[c] Damage at 90 days.

jars for toxicity exposures. The test jars were fitted with rings, 40-mesh brass screens, and filter paper lids.

The insects were exposed after the deposits had aged for 3, 6, 9, and 12 months. About 50 adult insects were placed in the individual 250-g samples. Prior to bioassay of the red and confused flour beetles, a 10-g sample was finely ground, then redistributed throughout the sample before the test insects were introduced. After 21 days' exposure, the adult insects were removed by sifting, and counts were made of the live and dead. The adults were discarded, but the grain and siftings were returned to the jars for later record of progeny development. Counts of rice weevil progeny were made 63 days after infestation, red flour beetles 70 days after infestation, and confused flour beetles and lesser grain borers 77 days after infestation. After the progeny readings were completed, the grain with the progeny was retained for at least 120 days for an assessment of progeny damage as described previously (La Hue 1969).

Malathion was used as a standard for comparison. An emulsifiable concentrate containing 57% of premium-grade malathion was diluted to make an emulsion for 1-ml applications to the grain to deposit 10 ppm actual malathion. Bioassays of the Gardona treatments were compared with bioassays of the malathion standard and of untreated wheat samples. The efficacy of the treatments was evaluated by determining the mortality of adult insects, by counting F_1 progeny, and by an assessment of the amount of damage caused by the progeny.

Supplemental studies were made as the test progressed. These included egg and larval survival counts in exposures with red and confused flour beetles.

RESULTS AND DISCUSSION.—Evaluations were made after 3, 6, 9, and 12 months' aging of the residues. Determinations of the moisture contents during the 12-month storage period showed very little change in the 12% wheat, but the changes in the 10% wheat ranged from +0.5 to −0.1%. The decrease in the moisture content of the 13.5% wheat ranged from 0.1 to 0.6 during the 12-month storage period.

Rice Weevil.—Table 1 summarizes the results from exposures of 21 days made at spaced intervals over a 12-month storage period. These data show that moisture content of the wheat is an important factor influencing

Table 2.—Mortality of adult red flour beetles and development of F_1 progeny after 21 days' exposure to residues of Gardona and malathion on hard winter wheat.

Aging period, insecticide, and dosage	10.0% moisture wheat			12.0% moisture wheat			13.5% moisture wheat		
		Progeny			Progeny			Progeny	
	Adult mortality	No.[a]	Damage rating[b]	Adult mortality	No.[a]	Damage rating[b]	Adult mortality	No.[a]	Damage rating[b]
3 months									
Gardona									
20 ppm	100.0	0	0	98.0	0	0	81.0	0	0
10 ppm	97.5	0	0	89.8	0	0	35.7	0	0
5 ppm	77.7	1.0	0	63.4	4.2	0	11.7	3.7	0.7
Malathion									
10 ppm	98.8	0	0	97.8	0.6	0	98.2	0	0
Untreated	2.8	20.2	1.7	0	32.8	2.3	1.8	27.9	2.3
6 months									
Gardona									
20 ppm	99.3	0	0	90.0	0	0	54.5	0	0
10 ppm	98.1	0	0	81.1	0	0	11.8	0.7	0
5 ppm	50.6	2.3	0	38.7	5.1	0.7	1.2	29.9	2.0
Malathion									
10 ppm	96.0	0	0	93.4	0	0	70.0	6.4	.2
Untreated	2.0	19.7	1.7	1.2	29.0	2.3	1.4	32.6	2.3
9 months									
Gardona									
20 ppm	96.9	0	0	48.4	0	0	29.2	0	0
10 ppm	47.4	0	0	37.0	11.2	.7	14.6	14.1	1.0
5 ppm	5.3	15.7	1.0	10.2	14.9	1.3	4.5	31.3	2.3
Malathion									
10 ppm	93.7	0	0	78.2	5.0	.7	53.7	16.9	1.4
Untreated	4.2	16.9	1.7	2.3	33.5	3.0	0	27.8	2.7
12 months									
Gardona									
20 ppm	98.0	3.0	0	40.1	3.1	0	16.9	4.0	0
10 ppm	21.6	7.8	0.3	2.9	21.7	1.7	1.3	15.0	1.3
5 ppm	6.4	26.2	2.0	4.0	36.0	3.0	1.9	28.7	2.7
Malathion									
10 ppm	89.8	7.4	.4	45.0	14.3	1.3	43.8	26.4	2.3
Untreated	4.2	23.9	2.3	0	31.1	3.0	2.3	33.9	2.7

[a] Progeny counts made 70 days after infestation.
[b] Damage 150 days after infestation ranged from 0 (no visible infestation or damage) to 3 (moderate infestation and considerable damage).

the effectiveness of Gardona and malathion against the rice weevil. The adverse effect of high moisture content on Gardona was compensated for, to some extent, by the increase in dosage. The 20 ppm application afforded excellent protection to 10.0% moisture wheat for 12 months, but for only 9 months to 12% wheat. All replicates of the 13.5% wheat treated with this dosage became infested in exposures made 3 months after treatment, even though adult mortality was 100%. On 10% wheat the 5 ppm application did not prevent F_1 progeny development and damage in tests made 3 months after treatment, but the 10-ppm dosage was effective against progeny damage for 6 months.

Malathion at 10 ppm gave excellent protection for 12 months to 10% wheat, for 9 months to 12% wheat, and for 3 months to 13.5% wheat. The rice weevil infestations which developed in the untreated check lots of 10% wheat were considerably less damaging than those in the 12 and 13.5% lots.

The numbers of F_1 progeny that emerged from treated samples were closely related to the mortality figures for the test insects; however, in some cases even when adult mortality was 100%, the F_1 progeny developed to maturity and damaging infestations were established.

Red Flour Beetles.—Adult mortalities resulting from exposure to treated 12 and 13.5% wheat were much less than on 10% wheat. The 20-ppm Gardona dosage was very effective against the adult red flour beetles on the 10% wheat for 12 months and on 12% wheat for 9 months (Table 2). This dosage limited the development of F_1 progeny in all samples from each moisture level, even though adult mortality dropped to as low as 16.9%. The 10-ppm dosage gave good protection to 10% wheat for 12 months, to 12% wheat for 9 months, and to 13.5% wheat for 6 months. The 5-ppm dosage gave good protection to wheat of all 3 moisture levels for 3 months, and to 10 and 12% wheat for 6 months.

In supplemental studies, samples of the 13.5% wheat treated with 20 ppm dosage were examined for red flour beetle eggs and larvae following mortality counts made 9 and 12 months after treatment. A considerable number of unhatched eggs and dead small larvae were found, indicating that egg depositions were not suppressed to a great degree by adult exposures to the residues remaining at that time. Surviving adults from these toxicity test samples deposited viable eggs when placed on untreated wheat, and the F_1 progeny production, although somewhat lower, compared favorably

Table 3.—Mortality of adult confused flour beetles and development of F_1 progeny after 21 days' exposure to residues of Gardona and malathion on hard winter wheat.

Aging period, insecticide, and dosage	10.0% moisture wheat			12.0% moisture wheat			13.5% moisture wheat		
		Progeny			Progeny			Progeny	
	Adult mortality	No.[a]	Damage rating[b]	Adult mortality	No.[a]	Damage rating[b]	Adult mortality	No.[a]	Damage rating[b]
3 months									
Gardona									
20 ppm	97.3	0	0	88.9	0	0	40.2	0	0
10 ppm	69.1	0	0	40.1	11.0	0.3	10.2	6.3	0.3
5 ppm	2.5	7.0	0	4.0	40.4	1.7	0.6	34.0	1.7
Malathion									
10 ppm	100	0	0	100	0	0	92.0	0	0
Untreated	0.7	31.9	2.0	0	52.0	3.0	0	57.1	2.7
6 months									
Gardona									
20 ppm	98.8	0	0	64.4	0	0	32.2	0	0
10 ppm	64.0	0	0	11.1	17.1	.3	8.3	11.7	.7
5 ppm	5.1	9.3	0	7.6	37.6	1.7	3.7	31.3	2.3
Malathion									
10 ppm	100	0	0	97.6	0	0	81.1	4.5	0
Untreated	1.2	26.3	2.0	0	49.8	2.7	0	42.0	2.7
9 months									
Gardona									
20 ppm	90.2	0	0	47.3	3.1	0	17.7	0.7	0
10 ppm	31.5	0	0	16.0	11.2	.7	11.3	15.3	1.0
5 ppm	7.9	13.0	0.3	5.4	37.7	1.7	5.7	52.7	2.7
Malathion									
10 ppm	79.9	4.2	0	60.7	3.2	.2	60.4	10.0	.8
Untreated	0	27.7	1.8	0	41.7	2.7	0	49.7	3.0
12 months									
Gardona									
20 ppm	73.2	0	0	30.1	7.4	0	18.5	13.0	3.3
10 ppm	43.9	3.0	.7	6.7	33.4	1.7	3.9	33.7	2.3
5 ppm	1.3	20.0	1.3	7.6	46.1	2.7	3.8	45.3	2.7
Malathion									
10 ppm	78.5	21.	0	35.8	9.4	.4	31.4	21.5	1.8
Untreated	1.8	31.4	1.7	3.4	39.7	3.0	3.2	42.4	2.7

[a] Progeny counts made 77 days after infestation.
[b] Damage 150 days after infestation ranged from 0 (no visible infestation or damage) to 3 (moderate infestation and considerable damage).

with the hatch from depositions by adults taken from the untreated check samples.

Although the 10-ppm dosage of malathion was effective against the red flour beetle on the 10% wheat for 12 months, its efficacy on the 12 and 13.5% wheat decreased after 6 months' storage.

Confused Flour Beetles.—Data presented in Table 3 show the marked reduction in effectiveness against adult confused flour beetles attributable to dosage, age of residue, and moisture content of the treated grain. The 20-ppm application of Gardona prevented progeny damage at the 10 and 12% moisture levels; however, a few progeny were found in samples containing 13.5% moisture. The 10-ppm dosage protected against progeny damage in 10% wheat for 9 months, and in 12% wheat for 3 months. The 5-ppm dosage protected 10% wheat against progeny damage for 6 months.

No F_1 progeny developed in 13.5% wheat treated at 20 ppm after the 3-month bioassay, even though 59.8% of the adults had survived the killing action of the residues during the 21-day toxicity test exposures. Supplemental studies were made with the toxicity test samples aged 6 and 9 months to determine whether eggs were deposited during the exposures, and if so, whether they were viable. Approximately 68 and 82% of the adults survived in the 6- and 9-month toxicity test exposures, respectively. An average of about 21 and 24 eggs, respectively, were found in the treated samples after these 2 aging periods, in comparison with about 37 and 35 eggs in untreated samples. Some eggs were evidently overlooked as about 46 F_1 progeny, on an average, emerged from the untreated wheat samples. The egg hatch in the treated samples was erratic, and most of the newly hatched larvae died before molting.

Malathion exhibited a high degree of effectiveness by greatly reducing progeny production and damage in 10% wheat for 12 months, but there was some progeny damage at 9 months in 12 and 13.5% moisture wheat.

Lesser Grain Borers.—The 20-ppm dosage of Gardona on 10% wheat gave 100% mortality of lesser grain borer adults for only 3 months, and progeny damage was recorded in all tests conducted after 9 months' storage (Table 4). The progeny inflicted considerably more damage to comparable samples from the different treatments than was inflicted by the progeny of the other test species.

Malathion protected the 10% wheat for 9 months, the 12% for 6 months, and the 13.5% for 3 months.

Table 4.—Mortality of adult lesser grain borers and development of F_1 progeny after 21 days' exposure to residues of Gardona and malathion on hard winter wheat.

Aging period, insecticide, and dosage	10.0% moisture wheat			12.0% moisture wheat			13.5% moisture wheat		
	Adult mortality	Progeny No.[a]	Progeny Damage rating[b]	Adult mortality	Progeny No.[a]	Progeny Damage rating[b]	Adult mortality	Progeny No.[a]	Progeny Damage rating[b]
3 months									
Gardona									
20 ppm	100	0	0	94.9	10.0	1.0	86.8	77.0	2.0
10 ppm	94.2	22.0	0.7	79.6	28.9	1.7	25.7	289.0	3.7
5 ppm	66.2	221.0	3.0	31.3	211.7	3.3	4.1	965.3	5.0
Malathion									
10 ppm	100	0	0	100	0	0	95.5	0	0
Untreated	3.2	796.7	5.0	2.7	978.4	5.0[c]	4.4	1198.4	5.0[c]
6 months									
Gardona									
20 ppm	94.1	5.0	0	79.9	131.0	1.3	46.3	232.1	3.7
10 ppm	86.6	90.3	1.3	69.8	327.4	3.3	9.8	685.7	5.0
5 ppm	14.1	366.1	3.3	7.7	593.9	4.3	0.6	1081.0	5.0[c]
Malathion									
10 ppm	96.6	7.2	0	88.6	16.4	0	80.2	46.0	0.4
Untreated	5.0	884.0	5.0	4.3	1094.3	5.0[c]	4.0	1214.0	5.0[c]
9 months									
Gardona									
20 ppm	92.3	15.3	1.0	60.1	320.4	3.0	21.0	629.0	4.3
10 ppm	48.9	259.0	3.7	10.1	796.1	4.7	3.7	1150.1	5.0
5 ppm	3.9	918.0	5.0	7.4	1171.9	5.0[c]	11.8	1375.0	5.0[c]
Malathion									
10 ppm	90.0	12.3	.4	84.4	70.0	1.2	70.0	94.5	2.3
Untreated	4.6	897.0	5.0	5.1	1116.7	5.0[c]	3.0	1109.6	5.0[c]
12 months									
Gardona									
20 ppm	90.6	17.0	1.3	31.1	743.0	4.3	9.8	951.1	5.0
10 ppm	37.9	201.1	3.3	11.4	916.6	5.0	8.9	1032.3	5.0[c]
5 ppm	4.2	810.7	5.0	3.9	1201.0	5.0[c]	9.6	1162.9	5.0[c]
Malathion									
10 ppm	76.7	39.8	2.0	39.9	214.0	2.8	40.6	482.0	3.8
Untreated	3.2	877.8	5.0	3.9	1056.0	5.0[c]	4.2	969.3	5.0[c]

[a] Progeny counts made 77 days after infestation.
[b] Damage 150 days after infestation ranged from 0 (no visible infestation or damage) to 5 (heavy infestation, damage and grain spoilage).
[c] Damage at 120 days.

Conclusion.—Effectiveness of Gardona applied at a dosage of 10 ppm to wheat containing 10, 12, and 13.5% moisture compared favorably with that of malathion in tests with red and confused flour beetles. These findings generally agree with those of Lemon (1967). However, in tests with rice weevils and lesser grain borers, malathion was usually more effective than Gardona. Moisture content of the wheat was an important factor influencing the efficacy of both Gardona and malathion. The adverse effect of high moisture was compensated for to some extent by increasing the dosage of Gardona.

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