Evaluation of Dichlorvos for Insect Control in Stored Rough Rice[1,2]

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ABSTRACT

Dichlorvos was evaluated as a direct-spray application at 5, 10, 15, and 20 ppm in comparison with malathion at 14 ppm for insect control in rough rice. Jar tests and small-bin tests were used. Jar tests revealed short-term protection by dichlorvos against infestation by rice weevils, *Sitophilus oryzae* (L.), and lesser grain borers, *Rhyzopertha dominica* (F.). Confused flour beetles, *Tribolium confusum* Jacquelin duVal, were controlled immediately after treatment but not at subsequent intervals. Dichlorvos was more effective than malathion in reducing rice weevil emergence. While high moisture content of the rice at the time of treatment adversely affected the duration of protection, it had no obvious immediate effect, because nearly complete control of the rice weevil was obtained at the time of treatment. This control occurred in jar tests and in small bin tests. Residues on rough rice were as high as 7.3 ppm 24 hr after treatment, but in 30 days they were 0.87 ppm on rough rice, 3.1 in hulls, 0.41 in bran, 0.03 in brown rice, and 0.02 in milled rice.

Numerous investigators have studied the application and effectiveness of dichlorvos aerosols and vapors for controlling household and medically important arthropods and for moths infesting stored products. However, studies of the material's application and effectiveness for controlling stored-product beetles have been quite limited.

The control of the cigarette beetle, *Lasioderma serricorne* (F.), in tobacco warehouses by dichlorvos aerosols alone and in conjunction with other treatments has been reported as being successful (Tenhet et al. 1958, Childs et al. 1966, Childs 1967). Jay et al. (1964) reported the toxicity of several formulations of dichlorvos to confused flour beetles, *Tribolium confusum* Jacquelin duVal. Dichlorvos was reported by Stern et al. (1968) to be an effective protectant against insect damage to herbarium specimens. Schesser (1967) successfully used dichlorvos-malathion mixtures for disinfesting empty rail cars. Dichlorvos was shown to control infestations of the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.), in barley at dosages as low as 4 ppm, but no lasting protection was observed (Green and Tyler 1966). In laboratory tests (Kirkpatrick et al. 1968) dichlorvos was shown to be of limited effectiveness as a protectant when applied to wheat with 12% moisture content, and very effective against rice weevils, *Sitophilus oryzae* (L.), when the insects were introduced immediately after treatment.

In a series of studies reported by Strong and Sbur (1961, 1964a, 1964b), very good initial mortalities of rice weevils, granary weevils, *Sitophilus granarius* (L.), and confused flour beetles were observed in laboratory tests on wheat with dichlorvos dosages below 10 ppm. In the 2nd study (1964a), high grain moisture content and high temperature were found to degrade dichlorvos very rapidly, but apparently without affecting the initial effectiveness of the treatment. In the 3rd study (1964b), they found that dichlorvos, in contrast with malathion, was effective against internal infestations and, further, they suggested that dichlorvos might be used successfully when grain was received in infested condition at facilities where fumigation was not possible or feasible.

Rice mills receive rice under climatic conditions that are very favorable for insect infestation and are predominantly of such construction that fumigation would not be successful or desirable. Furthermore, rice received by mills is usually placed in short-term storage (for ca. 30 days) where persistent chemicals would result in excessive residues on one or more of the milling fractions of rice if the rice were milled soon after treatment (McGaughey 1969). Dichlorvos, being relatively nonpersistent, might then be suitable for application directly to the rice as it is moved into the storage facilities of the mills; most mills have equipment available to apply chemicals at that time.

The study reported here was conducted to determine the effectiveness of dichlorvos applications in disinfesting and protecting stored rough rice, to evaluate the effect of moisture content of the rice on the duration of effectiveness and to determine the persistence of dichlorvos residues on rough rice and its milling fractions. Jar tests and small-bin tests were made.

Methods and Materials.—Insects used for tests were reared at 27°C and 60% RH. Rice weevils and lesser grain borers, *Rhyzopertha dominica* (F.), were reared in brown rice, and averaged 14 days old when used in tests. Rice weevil larvae were used when the cultures were 3 weeks old and were contained in 50 g of brown rice. Confused flour beetles were reared in a mixture of flour and corn meal and were used in tests when the adults averaged 14 days old. Four separate tests were conducted and 3 varieties of rough rice of various moisture contents were used.

The dichlorvos sprays were prepared by diluting 23.5% EC with distilled water to provide appropriate concentrations for application to the rice. Malathion sprays for comparisons were prepared in the same manner by diluting 57% EC with distilled water. Appropriate sprays were applied in jar tests by pipetting 1 ml of the chemical onto the inner surface of each rotating 3.79-liter jar containing the rice. The jar was then tumbled for 10 min to insure even distribution of the chemical on the rice. All samples and subsamples from jar tests were held at 27°C and 60% RH.

Jar Test 1.—The duration of protection afforded by dichlorvos was evaluated by treating 1200-g samples of noninfested 'Bluebelle' rough rice (moisture content 12.4%) with 1 ml of the appropriate concentration of a water emulsion of the chemical to achieve dosages of 5, 10, and 20 ppm. After the samples were treated, 150-g subsamples were taken from each lot

[1] Received for publication Apr. 13, 1970.
[2] Mention of a proprietary product does not necessarily imply endorsement by the USDA.
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Table 1.—Duration in weeks of effective (>98%) control of insects introduced 0, 3, 6, and 9 weeks after treatment and exposed for 3 weeks in rough rice treated with malathion or dichlorvos in jar tests.[a]

Insect	Weeks of effective control with			
	Malathion 14 ppm	Dichlorvos		
		5 ppm	10 ppm	20 ppm
Rice weevil adults	>9–12	0–3	0–3	3– 6
Rice weevil larvae[b]	NE[c]	NE[c]	0–6	0– 6
Lesser grain borer	>9–12	0–3	0–3	9–12
Confused flour beetle	6– 9	NE[c]	0–3	0– 3

[a] Each value is based on 3 replications.
[b] Values are based on % reduction of adult emergence after 6-weeks exposure.
[c] Indicates noneffectiveness in the initial interval.

and held in 0.473-liter jars with filter-paper caps. Rice weevil adults, rice weevil larvae, lesser grain borer adults, and confused flour beetle adults were introduced into subsamples immediately after treatment of the rice and 3, 6, and 9 weeks after treatment. Adults were exposed for 3 weeks; larvae, which were contained in 50 g of brown rice, were exposed for 6 weeks. Three replicates were used for each type of insect and treatment at each time interval.

Jar Test 2.—Effect of moisture content of the rice on the duration of protection was evaluated by adjusting the moisture content of Bluebelle rough rice to 12, 13, and 14% by adding distilled water or by drying as required. The rice was treated in 1000-g lots in 3.79-liter jars with 1 ml of the appropriate concentration of dichlorvos to achieve a deposit of 10 ppm. Subsamples of 150 g were taken from each lot and were infested with rice weevils at weekly intervals. Exposure periods of 3 weeks were used. All subsamples were held in 0.473-liter jars with filter-paper caps.

Jar Test 3.—Effectiveness of dichlorvos as a control treatment for infested rice was first evaluated in jar tests. Rice for the tests was taken from 4 containers of rough rice heavily infested with rice weevils and with lighter infestations of several other species. Two of the containers were 'Dawn' variety, 1 was 'Nato', and 1 was Bluebelle. The moisture contents of these lots ranged from 13.8 to 14.3%. Five 1000-g samples were drawn from each of the 4 containers—1 control, 1 to be treated with 14 ppm malathion, and 1 each for treatment with 5, 10, and 20 ppm dichlorvos. The rice in each container was blended prior to drawing of the samples to insure equal populations in the 5 samples. The resident population was a natural one, expected to have a normal distribution of eggs, larvae, pupae, adults, and dead adults.

The samples were treated by pipetting 1 ml of the appropriate concentration of chemical onto the inner side of a rotating 3.79-liter jar containing the sample. After the samples were treated they were transferred to fresh jars and closed with screened lids having a 50-mm hole covered with filter paper. The control samples were treated with water and handled in the same manner as the chemically treated samples.

Small-Bin Test. — Effectiveness of dichlorvos was evaluated also in small-bin tests using 1-bu (20.41-kg) lots of rough rice taken from the 4 containers which had a natural population of rice weevils and several other species. The moisture content of these lots at the time of treatment ranged from 13.5 to 14.0%. Each lot was treated in a cement mixer with 20 ml of the appropriate concentration of chemical to produce deposits of 5, 10, and 15 ppm. A sprayer, modified from that described by Hills and Taylor (1950) to hold a larger amount of chemical, was used with an air pressure of 10 psi to force the chemical through a TeeJet® TXSS1 ConeJet® nozzle onto the rice as it was mixed. Each lot was mixed for 5 min after treatment and was transferred to 27×27×53-cm foil-lined cardboard bins. The bins were held under ambient conditions with an average mean daily bin temperature of 30°C. The relative humidity fluctuated between 30 and 100%. The bins were arranged in a randomized-block design. Samples were taken for insect mortality determination and for residue analysis at 6 and 24 hr, and at 5, 10, 20, and 30 days. Additional mortality data were taken after 45 days.

Residue analyses were performed on milling fractions at 24 hr and 30 days. Only rough rice was analyzed at the other intervals. Milling fractions were prepared for analysis by shelling rough rice with a McGill sample sheller, milling the brown rice with a McGill no. 3 sample mill, aspirating the milled rice to remove traces of bran, and sifting the bran through a 30-mesh sieve to remove broken rice kernels. Mortality determinations of insects present in the rough rice were made by sifting 500 g of rice from each bin.

The effectiveness of remaining dichlorvos deposits in preventing reinfestation of the rough rice was evaluated at 2 and 4 weeks by placing rice weevils, lesser grain borers, and confused flour beetles in 0.473-liter jars each containing 150-g samples of rice from the treated bins. Eighteen-day exposure periods were used, and the samples were held at 27°C and 60% RH.

RESULTS.—*Jar Test 1.*—Table 1 presents the duration of protection afforded by dichlorvos in comparison with malathion in the 1st jar test. Effective control of each insect in the initial exposure interval was achieved at the 10- and 20-ppm levels of dichlorvos. Rice weevil adults and lesser grain borers were controlled in the initial interval at the 5-ppm level. Also, the 20-ppm treatment level was effective through the 3- to 6-week exposure interval against rice weevil adults, and throughout the 9-week test against lesser grain borers. In comparison, malathion at 14 ppm was effective against the 3 adult insects tested throughout the 9-week test. However, in the initial exposure

Table 2.—Corrected percent mortality of rice weevils introduced in jars at weekly intervals and exposed for 3 weeks on rice of 3 initial moisture contents treated with dichlorvos at 10 ppm in jar tests.[a]

Exposure interval (wk)	% mortality with initial moisture content of		
	12%	13%	14%
0–3	100	100	100
1–4	100	59	34
2–5	52	26	9
3–6	47	5	0
4–7	22	4	2
5–8	20	2	0

[a] Each value is the average of 2 replications.

Table 3.—Percent control of a rice weevil population in 1000-g lots of rough rice treated with malathion or dichlorvos in jar tests.[a]

Stage controlled	% control with			
	Malathion 14 ppm	Dichlorvos 5 ppm	Dichlorvos 10 ppm	Dichlorvos 20 ppm
Immatures[b] (2 wk)	51	37	42	60
Adults[c] (2 wk)	100	90	98	100
Population[b] (6 wk)	>99	>99	100	100

[a] Each value is based on 4 replications.
[b] % reduction in adult emergence.
[c] Mortality of all adults present 2 weeks after treatment.

period, dichlorvos was more effective at all dosages than was malathion against rice weevil larvae as measured by reduced adult emergence. The 10- and 20-ppm dosages of dichlorvos gave complete control and 5 ppm reduced emergence by 84%. The 14-ppm malathion treatment reduced emergence by 62%.

Jar Test 2.—Table 2 presents the effect of initial moisture content of rice on the duration of protection in the 2nd jar test. Mortalities of 100% were achieved at all moisture levels immediately after treatment, but decreased sharply at subsequent intervals. Toxicity was most persistent with an initial moisture content of 12%, intermediate at 13%, and shortest at 14%. Moisture in all samples had equilibrated to a range of 12.1–12.8% by the time mortality counts were made. Therefore, effects of moisture content of the rice only at the time of treatment and not throughout the test were determined.

Jar Test 3.—Table 3 presents results of the 3rd jar test to determine the effectiveness of dichlorvos as a treatment for infested rice. Reduction in rice weevil emergence is indicated as well as good control of adult rice weevils. The presence of adult insects at the time of treatment causes the reduction in emergence of immatures to appear less than might otherwise be expected. Progeny were virtually eliminated by all treatments after 6 weeks. No flour beetles were present in these samples, but Angoumois grain moth, *Sitotroga cerealella* (Olivier), emergence was completely eliminated by all dichlorvos treatments. Malathion suppressed but did not eliminate moth activity.

Small-Bin Test.—Table 4 presents the effectiveness of dichlorvos in eliminating established rice weevil infestations in small bins. As the data indicate, virtually complete control of the resident rice weevil population was achieved with each treatment level. Migration of weevils from control bins into treated bins may account for the lack of 100% mortality at later intervals. Toxicity tests in 0.473-liter jars containing 150-g samples taken from these bins at 2 weeks and at 4 weeks revealed almost no protection against reinvasion by rice weevils, lesser grain borers, or confused flour beetles. Thus, the initial mortality effects of dichlorvos were the only result of this treatment. Toxicity of the deposits did not persist, probably because of the high moisture content of the rice (13.5–14.0%) at the time of treatment. The 2nd-jar test (Table 2) demonstrated the effects of such high initial moisture contents on the persistence of effectiveness. However, moisture had no obvious effect on the performance of dichlorvos as a control treatment.

Table 4.—Corrected percent mortality of adult rice weevils in rough rice in small bins at 7 intervals after treatment with 3 dosages of dichlorvos.[a]

Interval	% mortality with dosage of		
	5 ppm	10 ppm	15 ppm
6 hr	100	100	100
24 hr	100	100	96
5 days	95	100	100
10 days	89	100	100
20 days	93	93	100
30 days	97	93	98
45 days	82	89	93

[a] Each figure is the average of 4 replications.

Table 5.—Dichlorvos residues (ppm) on rough rice at 6 intervals after treatment with dichlorvos in small bins.[a]

Treatment ppm	Residue after time interval of					
	6 hr	24 hr	5 days	10 days	20 days	30 days
0	<0.02	<0.02	0.04	<0.02	<0.02	<0.02
5	.67	1.6		.90	.38	.22
10	1.3	4.6	1.1	1.5	.77	
15	5.8	7.3	3.0	3.0	2.7	.87

[a] Each value is based on analysis of a single composite of subsamples from each of 4 replicates. Limit of detection was 0.02 ppm, and values are not corrected for apparent residue levels on untreated samples.

Tables 5 and 6, respectively, present residue levels on rough rice from the small bins at 6 intervals and on the milling fractions at 2 intervals after treatment. Analyses were performed by the Pesticide Laboratory, Agricultural Chemicals Division, Shell Chemical Co., Princeton, N. J.

Although residues were high on rough rice and milling fractions 24 hr after treatment, analyses performed at 30 days indicate that dichlorvos residues at that time, with the exception of those on rice hulls, were so low as to be of little significance. Present and potential uses of rice hulls render those residue levels to be of small significance.

Table 6.—Dichlorvos residues (ppm) on milling fractions of treated rough rice at 2 time intervals after treatment in small bins.[a]

Time interval	Treatment ppm	Hulls	Brown rice	Bran	Milled rice
24 hr	0	0.15	<0.02	0.03	0.02
	5	8.0	.30	2.0	.02
	10	20.0	.32	5.1	.02
	15	37.	.62	7.7	.03
30 days	0	< .02	.02	.02	< .02
	5	1.3	.03	.10	
	10	2.4	.05	.24	.02
	15	3.1	.03	.41	

[a] Each value is based on analysis of a single composite of subsamples from each of 4 replicates. Limit of detection was 0.02 ppm, and values are not corrected for apparent residue levels on untreated samples.

DISCUSSION.—Dichlorvos appears suitable for use where fumigation is not feasible or where persistent residues must be avoided. Levels of 5 ppm achieved virtually complete control of rice weevil infestations in jar tests. Although protection against reinfestation was greatly reduced at high moisture levels (13–14%), jar tests suggested that 20 ppm was effective against infestation by rice weevils for 3–6 weeks, and against lesser grain borers for 9–12 weeks with rice moisture contents of 12.4% at the time of treatment. Small-bin tests demonstrated effective control with 5, 10, and 15 ppm dichlorvos, but did not indicate protection against reinfestation at the initial moisture levels used (13.5–14.0%).

Such treatments could be applied with existing equipment in most rice mills and could possibly eliminate problems associated with receiving infested rough rice. At moisture contents of 12.5% or less at the time of treatment, control should persist long enough to keep the rough rice insect free while in short-term (30 day) storage at the mill. Residue levels reported here are such that they appear to be of little concern after 30 days.

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Reprinted from the
JOURNAL OF ECONOMIC ENTOMOLOGY
Volume 63, Number 6, pp. 1867–1870, December 1970