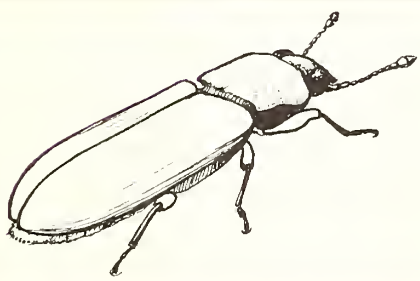
Marketing Research Report No. 234

Evaluation of Lindane for the Protection of Stored Wheat and Shelled Corn from Insect Attack



Marketing Research Division
Agricultural Marketing Service
U. S. DEPARTMENT OF AGRICULTURE

WARNING

No tolerances have been established for the use of lindane as an insecticidal treatment for the prevention of insect infestation in stored grain. The tests reported herein were exploratory studies to develop information that could be used in considering the establishment of tolerances. Until such tolerances are announced, lindane protective treatments should not be used.

This report is the second of a group presenting results of tests with various insecticidal dusts and sprays applied to stored grain for protection against insect attack. These reports are a part of a broad program of research to reduce the cost of marketing farm products, including the cost of preventing insect infestation in stored grain.

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CONTENTS

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EVALUATION OF LINDANE FOR THE PROTECTION OF STORED WHEAT AND SHELLED CORN FROM INSECT ATTACK

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SUMMARY

This report presents results of tests with various insecticidal dusts and sprays applied to stored grain for protection from insect attack. It summarizes the tests with lindane made in the period October 1952 through December 1956. Because of the interest in protective sprays and dusts for stored grain, results to date are published even though the studies are being continued.

The studies were conducted on wheat and shelled corn in the standard circular 3,250-bushel metal bins of the Commodity Credit Corporation, U. S. Department of Agriculture. After the protective treatments were applied, the grain was sampled monthly to determine the insect population trends, moisture content of the grain, insecticidal residues, depletion of insecticide by bioassay tests, and commercial grade. In tests with wheat, the fate of the insecticides was traced through milling and baking tests.

Four series of tests were made, one with wheat and three with corn, at dosages of 2.5 and 5 p.p.m. (parts per million) in wheat, and 2.7, 4.5, 5.4, 8.0, and 10.7 p.p.m. in corn. Observations on insect population trends showed that these dosages were inadequate to protect the grain from excessive insect infestation for long periods of time (1 year or more).

In wheat receiving 2.5 p.p.m., the recovery of lindane in the residue analyses was frequently in excess of the application rate. In the series receiving 5 p.p.m., the recovery was close to the amount applied.

Milling tests showed that the lindane was carried over into the milling fractions, the largest amounts being found in the bran and shorts. Small amounts were found in the first and second clear flours, with less than 1 p.p.m. in the patent flour.

In bread baked from flour containing known amounts of lindane, it was found that baking reduced the residue only slightly.

1/ This laboratory is a field station of the Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

Bioassay tests and chemical analyses showed that there was very little depletion of the lindane with age.

There was no change in the overall moisture content of the grain during the period of these studies.

No change in the commercial grade occurred during the observation period.

In the tests with shelled corn, the residues found in the corn receiving 2.7 p.p.m. were about 90 percent of the application rate; at 4.5 p.p.m. the recovery was 69 percent, and at 5.4 p.p.m., 56 percent.

Analysis of residues from 16 locations in the corn in 1 bin showed that the largest amounts were found in the upper 5 feet of corn.

The moisture content of the corn changed only slightly during the period of these tests.

The commercial grade was not affected by the treatments. However, the corn in 15 of 29 bins in the study was down-graded from 1 to 5 grades because of the increase in the grade factor "total damage", due largely to accumulated moisture in the surface grain during the winter months.

Eight species of stored-grain insects were found in the wheat, the 3 most abundant being the saw-toothed grain beetle, the dermestids *Trogoderma* spp., and the lesser grain borer.

In corn, a total of 15 species was observed, the 3 most abundant being the saw-toothed grain beetle, the red flour beetle, and the flat grain beetle.

BACKGROUND AND PURPOSE OF THE WORK

This is the second of a group of reports presenting the results of tests with several insecticidal sprays and dusts when applied to stored grain for protection from insect attack. It is limited to tests made with lindane in stored wheat and shelled corn.

The huge reserves of grain accumulated as a result of increased yields and the loan program have necessitated changes in grain handling and storage practices. Grain is stored for much longer periods, and new and improved methods of insect control are required.

In line with the trend toward preventive rather than curative methods of insect control, intensive studies were begun in the fall of 1952 to explore the feasibility of applying insecticidal dusts and sprays directly to stored wheat and shelled corn to inhibit the development of insect infestation. The use of insecticides in this manner introduces numerous problems.

For example, the residues of insecticide on the grain must be studied to determine whether they are within safe limits for the ultimate consumer--human beings or livestock--and whether the treatment affected the quality of the grain.

Much information has been accumulated during the past 4 years, which is presented in this report. The studies have not as yet been completed, and a further report will be made at their conclusion. For clarity in presentation, the data were divided into two parts, one part covering the tests with stored wheat, the other with stored shelled corn.

TECHNIQUE

The tests were conducted in USDA circular metal bins, 16 feet in height and 18 feet in diameter, with a capacity of 3,250 bushels. The dust was applied either by hand as the grain was run from the auger, or by a mechanical applicator attached to the auger tube.

Samples were drawn at monthly intervals after the dust was applied, and the number and kind of insects as well as the moisture content of the grain were determined.

Four series of tests were made, 1 with wheat and 3 with shelled corn. The tests with wheat were begun in May 1953 at Commodity Credit Corporation bin sites in Mitchell and Rush Counties, Kans., and involved 18 bins. The first series in shelled corn was started in September 1952 at a CCC bin site in Marshall County, Kans., and involved 5 bins. The second series was started in August 1953 at a CCC bin site also in Saline County, Mo., and it involved 19 bins. The third series was begun in August 1954, in Saline County, Mo., and it involved 11 bins.

Sampling Methods

Samples were drawn from 8 places in the grain mass for determinations of the insect population and moisture content of the grain. The samples were drawn with a 5-foot, or 10- or 11-celled, trier equipped with extension handles. Each sample amounted to about 500 grams. The samples were taken vertically in the center of the bin from the top, middle, and bottom 5 feet, from the top 5 feet in each quadrant at a location 3 feet from the wall, and horizontally at the center 2 to 3 inches from the top. Each sample was packaged separately and taken to the laboratory where it was screened and the number and species of insects recorded. The moisture content of each sample was determined with a dielectric moisture meter. When a bin of grain reached a level of insect population which would cause it to be designated as "weevily" under U. S. Grain Standards, it was dropped from the series and fumigated.

The sampling pattern in April, July, October, and December was extended to include vertical samples from the middle and bottom 5 feet in each quadrant. These were composited with the other samples from each bin after the insect and moisture records were taken. The composited sample was then separated with a grain divider into two or more subsamples in accordance with the sampling schedule. One subsample was analyzed for lindane residue. A second subsample for commercial grade was taken at the beginning of the test and annually thereafter or at the termination of the test. A third subsample was used in the bioassay tests.

Statistical Analyses

The performance of the insecticide was evaluated by comparing the treatments with the untreated controls and with each other on the basis of the number of "bin-months" of protection. The number of "bin-months" of protection was computed by dividing the total number of months of protection for a series of bins having the same treatment by the number of bins in that series. The treatment was considered to give protection until the insect population reached the level at which it would be designated as "weevily" under the provision of the U. S. Grain Standards current at the time of the tests. The grain was designated as "weevily" if a 1,000-gram sample contained living stored grain insects as follows: Wheat: 2 or more weevils, or 1 weevil and 3 or more bran beetles, or 5 or more bran beetles. Corn: 2 or more weevils, or 1 weevil and 5 or more bran beetles, or 25 or more bran beetles.

The data thus obtained were tested statistically for reliability by the analysis of variance method. The method of statistical analysis establishes the significance of mean differences between treated lots or between treated lots and the untreated controls.

Chemical Analyses

The analyses of the grain samples for residues of lindane and the analyses of bread were done by the Schechter-Hornstein method. 2/

The samples from the milling tests and from the milling fractions were analyzed by a modified Schechter-Hornstein method.

2/ Schechter, M. S., and Hornstein, I. Colorimetric determination of benzene hexachloride. Analyt. Chem. 24: 544-548. 1952.

Bioassay Tests

The bioassay tests consisted of confining, in 3 ounces of treated and untreated grain cut from the composited quarterly samples, 25 adults each of rice weevils and flour beetles and noting the mortality after 1 and 3 weeks.

TESTS WITH WHEAT

These tests were made to determine the degree of protection afforded by the lindane treatments, and the level of insecticidal residues in the wheat, in the milling fractions, and in the bread.

To attain these objectives, three types of tests were utilized: 1. Wheat was treated with lindane and the degree of protection determined by observation of the insect population trends; the amount of residue in the wheat and its persistence during the storage period was determined by chemical analyses and bioassays. 2. Wheat with a known amount of residue was milled and the amount of lindane in the screenings, aspirations, and milling fractions was determined by chemical analyses. 3. Bread was baked from flour containing known amounts of lindane and the residue was determined by chemical analyses.

Experimental Pattern

Performance Tests

Lindane dusts were applied in May 1953 to wheat stored at the Mitchell and Rush Counties, Kans., bin sites. Six bins were treated at the rate of 2.5 p.p.m. and six at 5 p.p.m. For the purpose of computing dosages, the p.p.m. for wheat were based on the weight of a standard bushel--60 pounds. Six untreated bins were used as controls. The dust was formulated on wheat flour at a concentration of 0.5 percent lindane and applied at the rates of 30 and 60 pounds per 1,000 bushels of wheat. Wheat flour was used as the carrier since past experience had shown that an inorganic carrier would impart a gritty feel to wheat and cause it to be downgraded.

The wheat was delivered from farm storage directly to the bin site, and as the wheat was emptied from each truck into the hopper of the auger, portions of the dust were applied by hand. It was expected that it would be well distributed by passage of the wheat through the auger tube and as it was discharged from the auger and cascaded into the bin (fig. 1).

Each bin was sampled monthly beginning in June 1953 through January 1956, to determine the insect population trends and the moisture content of the wheat. Quarterly and terminal samples for residue analyses, bioassay tests, and commercial grade were taken as described previously.

Milling Tests

One lot of approximately 120 bushels of wheat, designated as the "aged lindane," was withdrawn from a 3,250-bushel bin that had been treated with a 0.5-percent lindane dust formulated on wheat flour at the rate of 60 pounds per 1,000 bushels (5 p.p.m.) on June 17, 1953. This lot was sacked directly from the bin and trucked from the storage site in Rush County, Kans., to Manhattan, Kans., on October 2, 1954. The wheat was divided into 4 lots of 30 bushels each, 2 of which were milled at the Kansas State College pilot mill, and the other 2 at the commercial pilot mill at Minneapolis, Minn.

BN-5327

Figure 1.--Applying insecticidal dust by hand to wheat being emptied from trucks into hopper of elevating auger.

A second lot of 120 bushels designated as "fresh lindane" was treated on September 14, 1954, at the college mill with a 0.467-percent lindane (6.7 p.p.m.) emulsion. The spray was applied with an atomizing, fan-shaped spray nozzle as the wheat moved in a 6-inch, horizontal mixing-type screw conveyor. The treated wheat was conveyed approximately 20 feet and elevated into 3 bins. It was blended from these bins as it was sacked. This lot was divided into 4 lots of 30 bushels each, 2 of which were milled at the Kansas State College pilot mill, and the other 2 at the commercial pilot mill at Minneapolis. Two cleaning processes were employed at each mill, designated as the maximum and minimum. These differed in that the maximum cleaning involved washing the wheat prior to tempering.

In addition to the above lots, a 30-bushel lot of untreated wheat was milled at each mill to serve as standards.

During the milling process, samples for the determination of lindane residues were taken from 24 points as follows: 8 from the wheat before and during the cleaning and tempering process; 6 from different types of screenings; 5 from the different aspirators; 5 from the finals--bran, shorts, second clear flour, first clear flour, and patent flour.

The screenings, aspirations, and milling fractions were weighed to establish the proportions of each.

Baking Tests

Bread was baked from flour to which lindane had been added at rates of 1.25, 2.5, 5.0, and 10.0 p.p.m. Two bakings were made in February and two loaves with each concentration were prepared at each baking. Samples from each loaf were analyzed for lindane content to determine the degree to which residues were reduced by the baking process.

Insect Population Trends

The insect populations in the treated and check bins are shown in table 1. It may be noted that in the series receiving 2.5 p.p.m., 1 bin became "weevily" by November 1953, 2 more by August 1954, and 1 more by August 1955. At the time the series was discontinued in January 1956 only 2 of the original 6 bins remained insect free. In the series receiving 5 p.p.m., the wheat was practically insect free during the summer of 1953. During the summer of 1954, all but 1 of the bins developed serious infestation. In the untreated controls, 1 bin became weevily by October 1953, another by December 1953, 2 others by January and February of 1954, a fifth by October 1954, and the sixth by August 1955. From these results it is evident that lindane was ineffective in long-time protection at the dosages used in this work.

Statistical Analyses of Performance

As previously stated, the criterion for elimination of a bin of grain from a series was whether the insect population had reached a level that would be "weevily" according to U. S. Grain Standards. The mean number of months of protection was designated as the number of "bin-months" of protection. The bin-months of protection for the treated series compared with those of the controls were as follows:

Table 1.--Insect populations in wheat following applications of lindane at 2.5 and 5 p.p.m. in May 1953

Application rate and test number	Living insects found per 1,000 grams of wheat																															
	1953							1954												1955												1956
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
2.5 p.p.m. (30 lb./1,000 bu. 0.5 percent concentration)																																
1	0	0	0	0.5	0	0.5	1.75	1.75	0	0	0	0.25	0	0.25	9.75	1/																
2	0	.5	1.0	1.5	3.0	5.0	1/																									
3	0	0	.5	0	.25	.25	1.50	.5	.25	.25	0	1.5	.25	3.5	26.0	1/																
4	0	0	0	0	.5	.5	-	1.0	1.0	1.5	.25	1.5	.25	2.0	[illegible].75	0.25	0	1.25	0	0	0	0	1.0	0	0	0	0	-	0.5	0.5	-	0
5	.25	0	.25	.5	1.75	.75	-	.25	.5	1.25	0	0	.25	0	0	0	.5	.25	.75	.5	0	.5	0	0	0	0	.25	-	.25	0	-	0
6	0	0	0	0	0	.25	-	0	0	0	0	0		.25	0	.25	.25	0	.25	.75	0	.5	2.5	.5	0	0	7.25	1/				
5 p.p.m. (60 lb./1,000 bu. 0.5 percent concentration)																																
7	0	0	0	0	0	.5	0	.25	0	0	0	0	.5	2.5	6.75	1/																
8	0	0	0	0	0	0	.25	0	0	0	0	0	0	.5	1.5	6.25	1/															
9	0	0	0	0	0	0	0	0	0	0	0	.25	.5	1.75	5.75	1/																
10	0	0	0	0	0	0	-	.5	1.0	0	0	0	0	.5	1.0	.25	.5	.25	.25	.25	0	0	1	.5	0	0	.5	-	0	0	-	.25
11	0	0	.75	0	0	1.0	-	.5	.5	.5	0	.25	.5	1.25	14.5	1/																
12	0	0	0	0	0	0	-	.75	1.0	0	0	0	0	.5	.5	.25	1.75	7.0	1/													
Untreated controls																																
13	0	0	.75	2.0	14.0	1/																										
14	.25	0	2.0	1	1.5	.75	1.0	.5	.25	0	0	.25	.75	4.5	3.5	3.0	2.75	3.5	2.5	1.0	.5	3.0	0	.5	.25	1.5	10.25	1/				
15	1	4.25	1.5	2.75	2	1	5.75	1/																								
16	0	0	0	.25	.5	.25	-	0	.5	0	0	0	0	0	.25	1.5	8.75	1/														
17	.25	.5	0	1.25	.25	.25	-	6.25	1/																							
18	0	0	0	.5	.5	.5	-	2.25	6.5	1/																						

1/ Test terminated; grain reached weevily stage. After this count the bin was fumigated.

Treatment	Bin-months of protection
No treatment--controls	11.2
2.5 p.p.m.	20.5
5.0 p.p.m.	17.7

The differences between the treated lots and the controls, or between treated lots, were tested for significance by the method of analysis of variance. The analyses showed that the differences were not significant. The variation ratio "F" of 1.69 was less than the significant "F" value for this series of 3.68 at the 5 percent level.

The lack of significance was due to the wide variability in the number of bin-months' protection in both the treated series and the controls (table 1). A larger number of bins would be required to establish significant differences under these conditions.

Insecticidal Residues

In the Wheat

The lindane residues found in the composite samples (prepared by combining samples from 16 locations) are given in table 2. In the series receiving 2.5 p.p.m., the recovery was frequently in excess of the amount applied. The extremely high recoveries in test number 3 in August 1953 and July 1955 may have been due to agglomerations of the insecticide. In the series receiving 5 p.p.m., the recovery was close to the amount applied.

In 1 bin all 16 of the samples drawn in the October 1953 sampling were analyzed separately to obtain information on the uniformity of distribution of the insecticide in the grain mass. These data are given in table 3. The insecticide was distributed in a fairly uniform pattern.

In the Screenings, Aspirations, and Milling Fractions

The residues of aged lindane found in the wheat and in the milling products are given in table 4, and those of freshly applied lindane (6.7 p.p.m.) in the tabulation below:

Source of sample	Amount of lindane (p.p.m.)
Wheat as received	3.3
Cleaned wheat	3.4
Bran	11.0
Patent flour	.3

Table 2.--Residues on wheat at intervals during storage following applications of lindane at 2.5 and 5.0 p.p.m. in May 1953

Application rate and test number	Lindane present in--										
	1953		1954				1955				1956
	August	October	January	April	July	October	January	April	July	October	January
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
2.5 p.p.m. (30 lb./1,000 bu.) 0.5% concentration											
1	1/	-	-	-	-	2.0	-	2.0	-	-	-
2	3.2	2.8	2.1	3.0	2.4	1.8	-	-	-	-	-
3	8.4	1.4	1.8	3.7	3.0	3.0	2.6	.8	2/ 12.0	-	2.9
Means	5.8	2.1	2.0	3.3	2.7	2.3	2.6	1.4	2/ 12.0	-	2.9
5 p.p.m. (60 lb./1,000 bu.) 0.5% concentration											
4	5.0	4.8	2.7	3.0	3.3	2.9	-	-	-	-	-
5	-	-	-	-	-	3.8	-	-	-	-	-
6	-	-	-	-	-	3.2	-	-	-	-	-
7	4.5	7.5	4.6	5.1	3.4	3.9	4.7	-	2.0	3.1	4.8
Means	4.75	6.2	3.7	4.1	3.4	3.5	4.7	-	2.0	3.1	4.8

1/ No analysis.

2/ This value is questionable.

Table 3.--Distribution of lindane in a 3,250-bushel bin of wheat receiving an application in May 1953 of 60 lb./1,000 bu. of 0.5 percent dust (5 p.p.m.) and sampled in October 1953

Location of sample	Lindane present in wheat in --					
	Center of bin	North quadrant	East quadrant	South quadrant	West quadrant	Mean
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
Surface (top 2 in.)	4.5	-	-	-	-	4.5
Top 5 ft.	6.0	5.0	6.4	6.0	6.3	5.9
Middle 5 ft.	5.0	.5	8.0	3.0	4.4	4.2
Bottom 5 ft.	3.0	2.5	2.3	2.5	5.0	3.1
Means:						
Excluding surface	4.7	2.7	5.6	3.8	5.2	
Including surface	4.6					

The results showed that about half the freshly applied lindane was recovered from the wheat as received for milling. In the aged lindane, somewhat in excess of the amount applied was recovered. This would indicate that the lindane had been absorbed by the endosperm of the wheat. The largest portion of the residues were found in the feed fractions (bran and shorts) with about 5 p.p.m. in the second clear flour, 2 p.p.m. in the first clear flour, and less than 1 p.p.m. in the patent flour.

In the Bread

The residues found in bread made from flour to which lindane had been added are given in table 5. These results demonstrated that baking reduced the residue only slightly, the amount of reduction ranging from 0 to 16 percent as shown in table 6.

Table 4.--Residues in various milling products from wheat treated with lindane at the rate of 5 p.p.m. and aged for 15 months

Source of sample	Proportion of original weight of wheat	Milled at Manhattan		Milled at Minneapolis	
		Minimum cleaning series	Maximum cleaning series	Minimum cleaning series	Maximum cleaning series
	Percent	P.p.m.	P.p.m.	P.p.m.	P.p.m.
Before and during cleaning and tempering:					
Wheat as received	100.000	7.8	7.9	3.8	7.5
Wheat after Entoleter scourer aspirator		6.8	7.5	4.7	6.3
Screenings:					
From Millerator	.275	22.0	32.0	13.0	16.0
From Carter disc	.440	14.0	13.0	9.0	11.0
From aspirator	.772	12.0	11.0	2.1	3.1
From dry scourer	.207	9.0	10.0	11.0	15.0
From tempered scourer . . .	.222	9.3	14.0	27.0	29.0
From Entoleter scourer aspirator	.054	14.0	23.0	9.4	15.0
Aspirations:					
From Millerator	.098	4.2	4.8	-	-
From aspirator	.019	9.8	10.0	-	-
From dry scourer	.037	32.0	33.0	-	-
From tempered wheat scourer	.037	5.7	12.0	-	-
From Entoleter scourer aspirator	.093	3.5	3.6	-	-
Total cleanings and aspirations	2.254				
Finals:					
Bran	21.602	21.0	22.0	13.5	16.0
Shorts	8.406	16.0	18.5	[1] 16.0 [2] 11.0	[1] 23.0 [2] 13.0
2nd clear flour	3.656	4.9	4.9	4.0	5.3
1st Clear flour	10.126	1.8	2.1	1.8	2.3
Patent flour	53.956	.7	.6	.1	.9
Total finals	97.746				

1/ Head end shorts. 2/ Tail end shorts.

Table 5.--Residues in bread baked from flour containing known amounts of lindane, February 1954

Concentration of lindane in flour 1/	Lindane present in bread from --						
	First baking			Second baking			4-loaf mean
	Loaf No. 1	Loaf No. 2	Mean	Loaf No. 1	Loaf No. 2	Mean	
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
P.p.m.							
1.25	1.04	1.06	1.05	0.77	1.38	1.08	1.06
2.5	1.28	2.12	1.70	.90	1.18	1.04	1.37
5.0	1.90	2.84	2.37	1.96	2.41	2.19	2.28
10.0	6.50	8.30	7.40	3.78	5.08	4.43	5.92

1/ The amounts found by chemical analysis were respectively 1.11, 2.51, 3.81, and 9.13 p.p.m.

Table 6.--Reduction of residues during the baking process of bread made from flour containing known amounts of lindane

Lindane in flour	Mean weight of flour	Mean weight of loaves	Mean amount of lindane in bread	Reduction of residues1/
	Grams	Grams	P.p.m.	Percent
P.p.m.--				
1.11	315	485.0	1.06	0
2.51	315	484.8	1.37	16
3.81	315	484.5	2.28	8.1
9.13	315	486.0	5.92	0

1/ Reduction of residue = $\dfrac{\left(\dfrac{\text{Weight of flour}}{\text{Weight of loaf}} \times \text{residue in flour}\right) - \text{Residue in bread}}{\dfrac{\text{Weight of flour}}{\text{Weight of loaf}} \times \text{residue in flour}} \times 100$

Bioassay Tests

The results of the bioassay tests in wheat are given in table 7. There was no evidence of depletion of the lindane with age, the mortalities after 3 weeks of exposure being practically as high at the end of the observation period as at the beginning.

Moisture Content Changes in the Wheat

The wheat used in these tests was of low moisture content, most of it being below 11.0 percent. The moisture content of the samples taken from 16 locations in the bins showed that there was a continual transfer of moisture within the grain mass, but with little change in the overall content. There was no apparent effect on the behavior of the protective treatments attributable to variations in moisture content, nor was there any evidence that the protective treatments influenced the transfer of moisture or the amount of the moisture content.

Changes in the Commercial Grade

All of the wheat was graded as Number One Hard Winter when the study was begun, and there were no changes in the commercial grade during the period of the test.

TESTS WITH SHELLED CORN

The tests with shelled corn were directed toward determining the degree of protection against insect infestation afforded by the lindane treatments, the level of insecticidal residues, the distribution of the insecticide, changes in the moisture content, and changes in commercial grade during the storage period.

Experimental Pattern

In the first series of tests, the dust was applied in September 1952. One bin was treated with 1-percent lindane in corncob flour at the rate of 8.1 p.p.m., and another at 10.7 p.p.m. In the first bin the dust formulation was applied at the rate of 45 pounds per 1,000 bushels and in the second bin at 60 pounds per 1,000 bushels. The corn was of the 1949 crop and had been in storage on the site for 2 years prior to treatment. Three untreated bins served as controls. The corn was turned from one bin to another, and the dust was applied with a mechanical applicator attached to the tube of the elevating auger. It was expected that the dust would be well distributed as the corn passed through the auger and cascaded into the bins.

Table 7.--Mortality of adult rice weevils in bioassay tests with samples taken at intervals from wheat treated with lindane protective dusts

Application rate and length of confinement in weeks	Mortality in bioassay tests following sampling in-- 1/					
	1953		1954			
	August	October	January	April	July	October
	Percent	Percent	Percent	Percent	Percent	Percent
2.5 p.p.m. (0.5% concentration in wheat flour. 30 lb./1,000 bu.)						
1	100	79	72	59	50	51
3	100	100	99	99	96	98
5.0 p.p.m. (0.5% concentration in wheat flour. 60 lb./1,000 bu.)						
1	100	87	99	80	87	64
3	100	100	100	100	99	99
Untreated controls						
1	40	7	9	2	1	0
3	77	21	13	11	1	2

1/ Sampling periods correspond with those in table 2.

In the second series, started in August 1953, the corn was shelled on the farm and delivered directly to the bin site. As the corn from each truck was emptied into the hopper of the auger, aliquots of the dust were applied by hand.

Six bins were treated with 0.5-percent lindane in corncob flour at the rate of 2.7 p.p.m., and six at the rate of 5.4 p.p.m. In the first group the dust formulation was applied at the rate of 30 pounds per 1,000 bushels and in the second group at 60 pounds per 1,000 bushels. Six untreated bins served as controls.

In the third series, started in August 1954, treatment was delayed until all the corn had been loaded into the bins, and then the dust was applied as the corn was turned from one bin to another. The dust was applied by hand in aliquots as the grain dropped from the spout of the unloading auger to the hopper of the elevating auger. Five bins were treated with 0.25

percent lindane in corncob flour at a dosage rate of 4.5 p.p.m. The dust formulation was applied at the rate of 100 pounds per 1,000 bushels. Six untreated bins served as controls.

Each bin in the 3 treated series and the controls was sampled at monthly intervals following treatment to determine insect population trends and moisture content. A 5-foot grain trier or probe was used as in the wheat. The same pattern of sampling was used as for wheat, consisting of 8 probes, 1 in the top 5 feet in each quadrant, in the top, middle, and bottom 5 feet in the center, and 1 horizontal in the surface layer. This pattern was extended at each quarter to 16 probe samples consisting of the top, middle, and bottom 5 feet in each quadrant and the center, and 1 horizontal in the surface grain. After the insect population and moisture content of the corn had been determined, these samples were composited and samples were cut with a grain divider for residue analyses, commercial grade, and bioassay tests.

Bioassay tests were made for the purpose of observing any changes in the potency of the insecticide during the storage period. In these tests 25 adults each of rice weevils and flour beetles were confined on 3 ounces of corn from both the treated and untreated bins and the resulting mortality was recorded after 1 and 3 weeks.

In 1 bin all 16 of the samples were analyzed separately to obtain information on the distribution pattern of the insecticide.

Insect Population Trends

The trends of the insect populations in both the treated and control bins of the series started in September 1952 are presented in table 8. The corn treated with 8.1 p.p.m. became weevily by August 1953, whereas that treated with 10.7 p.p.m. did not develop a serious infestation until September 1954. The untreated controls became weevily by August and September 1953.

The insect populations in the series started in August 1953 are given in table 9. In the series receiving 2.7 p.p.m., 1 bin became weevily by November 1953, 2 in July and August 1954, and of the remaining 3, only 1 went through to February 1956 virtually free of insects. In the series receiving 5.4 p.p.m., the infestation remained low during the remainder of the 1953 season. In 1954, 1 bin became weevily by October, and 3 others developed light infestations. During 1955, 1 bin became weevily in July and 2 in September; the remaining 2 bins were carried through to December 1955 when the series was terminated. Six of the 7 controls became weevily by September and October 1953, the seventh becoming weevily by July 1954.

The insect populations in the series begun in August 1954 are given in table 10. The application rate of 4.5 p.p.m. permitted a light infestation to develop during the fall months after treatment. By August and September

Table 8.--Insect populations in shelled corn following application of lindane at 8.1 and 10.7 p.p.m. in September 1952

Application rate and test number	Living insects per 1,000 grams of shelled corn																						
	1952				1953										1954								
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
8.1 p.p.m. (45 lb./ 1,000 bu. 1% conc.)																							
1	1/	--	8.0	--	0	0	0	0	0	1.0	4.0	26.3	2/										
10.7 p.p.m. (60 lb./ 1,000 bu. 1% conc.)																							
2	--	--	.7	--	0	0	0	0	0	0	0	.7	0	0.7	2.3	0.3	0	0	0.3	0.7	6.7	6.3	54.3
Untreated controls																							
3	12.0	12.0	12.7	1.3	3.0	7.7	2.3	3.0	1.7	2.7	9.0	63.4	2/										
4	3.0	3.0	4.0	4.7	5.1	0	1.4	1.4	1.4	0	.4	2.7	20.0	2/									
5	2.3	2.3	1.3	1.3	.4	.7	1.4	0	1.4	.4	.4	3.0	30.0	2/									

1/ No sample taken.

2/ Test terminated; grain reached weevily stage. After this count the bin was fumigated.

Table 9.--Insect populations in shelled corn following application of lindane at 2.7 and 5.4 p.p.m. in August 1953

Living insects per 1,000 gram sample of shelled corn

Application rate and test number	1953 Aug.	1953 Sept.	1953 Oct.	1953 Nov.	1953 Dec.	1954 Feb.	1954 Mar.	1954 Apr.	1954 May	1954 June	1954 July	1954 Aug.	1954 Sept.	1954 Oct.	1954 Nov.	1954 Dec.	1955 Jan.	1955 Feb.	1955 Mar.	1955 Apr.	1955 May	1955 June	1955 July	1955 Aug.	1955 Sept.	1955 Oct.	1955 Nov.	1955 Dec.	1956 Feb.
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
2.7 p.p.m. (30 lb. /1,000 bu. 0.5 percent concentration)																													
1	0.5	2.75	7.25	36.3	2/																								
2	0	0	0	3.25	5.0	0.25	0	0	0	0	6.5	26.3	2/																
3	0	.5	2.5	7.75	15.8	.25	0	.5	.75	5.5	29.5	2/																	
4	0	0	.25	.25	.25	0	0	0	.25	0	0	3.5	1.5	6.75	11.3	2.75	0	1.75	1.75	1.0	0	0	3.5	8.25	20.0	15.0	7.5	1/	5.5
5	0	0	0	0	0	0	0	0	0	0	0	0	0	.25	.5	0	0	0	0	0	0	0	0	.5	3.5	2.75	1.25	-	6.75
6	0	.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.25	0	0	0	0	0	0	.25	0	-	.25
5.4 p.p.m. (60 lb. /1,000 bu. 0.5 percent concentration)																													
7	0	.25	1.5	0	.75	0	0	0	0	0	.25	5.5	14.5	38.5	2/														
8	0	0	0	0	0	0	0	0	0	0	0	1.0	1.5	1.25	1.25	2.0	0	.25	0	0	0	0	0	15.8	33.5	2/			
9	0	1.5	2.5	1.0	.25	0	.25	0	0	0	2.5	2.75	2.5	3.25	2.25	.25	0	1.25	.25	.25	4.25	9.5	31.5	2/					
10	-	0	0	0	0	0	0	0	0	0	0	0	.25	0	0	0	0	0	0	0	0	0	0	0	0	.5	.25	0	-
11	0	0	0	.25	0	0	0	0	0	0	0	0	.5	0	.5	0	0	0	0	0	0	0	0	6.0	29.8				
12	.25	0	1.25	0	.5	0	0	0	0	.25	0	0	0	2.25	1.0	.25	0	0	0	0	0	0	0	0	2.75	4.25	9.0	1.0	-
Untreated controls																													
13	2.0	40.0	2/																										
14	2.0	28.0																											
15	1.25	10.8	32.3	2/																									
16	1.75	14.3	92.8	2/																									
17	0	8.25	37.5	2/																									
18	0	8.0	17.5	2/																									
19	2.0	12.0	4.5	2.75	1.0	.25	0	.5	1.5	1.5	13.3	2/																	

1/ No sample taken.
2/ Test terminated; grain reached weevily stage. After this count the bin was fumigated.

Table 10.--Insect population in shelled corn following application of lindane at 4.5 p.p.m. in August 1954

Living insects per 1,000 grams of shelled corn

Application rate and test number	1954 Aug.	1954 Sept.	1954 Oct.	1954 Nov.	1954 Dec.	1955 Jan.	1955 Feb.	1955 Mar.	1955 Apr.	1955 May	1955 June	1955 July	1955 Aug.	1955 Sept.	1955 Oct.	1955 Nov.	1955 Dec.	1956 Jan.	1956 Feb.	1956 Mar.	1956 Apr.	1956 May	1956 June	1956 July	1956 Aug.	1956 Sept.
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
4.5 p.p.m. (100 lb. /1,000 bu. 0.25 percent concentration)																										
1	0	0	0	2.5	0.25	0	0	0.5	0	0	0	9.25	31.5	1/												
2	0	.5	.25	0	0	0	0	0	0	0	0	.5	9.5	25.5	1/											
3	.25	1.0	1.5	1.0	.5	0	0	0	0	0	2.25	21.5	32.3	1/												
4	0	0	.25	1.75	0	0	0	0	0	0	.25	9.5	24.5	69.5	1/											
5	0	.5	0	.25	0	0	0	0	0	0	0	.75	9.25	30.8	1/											
Untreated controls																										
6	2.25	6.5	3.5	5.0	22.5	3.5	.75	1.0	0	0	1.25	1.25	9.75	18.5	3.5	2/	3.5	—	1.25	3.75	0.75	1.25	4.0	16.0	0	0
7	1.75	5.75	2.75	2.0	.5	.25	0	.25	.5	0	1.12	2.0	13.3	10.8	9.0	1.0	—	—	2.0	0	0	0	.25	4.5	19.3	8.3
8	0	1.25	.75	2.75	0	0	0	0	0	0	0	.75	5.0	30.5	1/											
9	.75	4.75	1.75	1.25	2.5	3.5	1.0	.25	1.0	0	0	.5	6.0	9.75	2.25	--	3.5	—	4.5	2.0	2.0	0	4.75	16.8	0	.75
10	6.5	6.75	5.25	7.0	4.5	2.25	5.5	.50	0	0	0	1.25	13.0	23.5	4.9	--	2.0	--	12.7	0	0	0	0	2.0	9.0	6.75
	2.25	4.25	.75	1.75	0	.25	.5	.25	0	0	0	2.75	13.0	25.5	1/											

1/ Test terminated; grain reached weevily stage. After this count the bin was fumigated.

2/ No sample taken.

1955 the entire series became weevily. In the control series, a rather high infestation level developed in all of the bins but reached the weevily point in only two of the bins. For practical purposes, both series developed dangerous insect populations by September 1955.

Statistical Analyses of Performance

The data on the performance of the insecticide as applied to corn were handled in the same manner as for wheat. Bins were eliminated from a series as they became weevily, and the number of bin-months of protection computed as for wheat.

The bin-months of protection for the first series of tests begun in September 1952 in Marshall County, Kans., are given below:

Treatment	Bin-months of protection
No treatment--controls	11.7
8.1 p.p.m.	11.0
10.7 p.p.m.	24.0

Because only 1 bin was treated at each of the concentrations, and there were 3 bins in the untreated control, the data could not be evaluated statistically. However, on the basis of bin-months of protection, there was no difference between the bin treated with 8.1 p.p.m. and the control. The grain in the bin treated with the higher dosage (10.7 p.p.m.) was protected for more than twice as long as the grain in the bin treated with 8.1 p.p.m. and in the control.

The bin-months of protection for the second series of tests begun in August 1953 in Saline County, Mo., are given below:

Treatment	Bin-months of protection
No treatment--controls	3.7
2.7 p.p.m.	20.3
5.4 p.p.m.	24.2

When tested for significance by the method of the analysis of variance, the mean difference between the treated series was not significantly different, but the difference between the treated lots and the untreated controls was highly significant beyond the 1-percent level. The variation ratio "F" was 12.51, much greater than the value of 3.63 required for significance for this group of bins.

The bin-months of protection for the third series of tests begun in August 1954 were as follows:

Treatment	Bin-months of protection
No treatment--controls	21.7
4.5 p.p.m.	12.6

In this series the insect populations were lower in the controls than in the treated series. Manifestly, this treatment failed to protect the grain. However, as noted in the discussion of the development of insect infestation of this series (table 10) the controls became heavily infested but not weevily at about the same time as the treated series.

Insecticidal Residues

The residues found in the composited samples taken quarterly are given in tables 11 and 12. At the lower rate of application (2.7 p.p.m.) the residue found in the corn was about 90 percent of the application rate; at 4.5 p.p.m. the recovery was 69 percent and at 5.4 p.p.m., 56 percent. Consecutive analyses from a given test were often quite variable. This may have been due to a combination of uneven distribution of the lindane in the grain and sampling error. From these data, the depletion of the lindane with age was gradual.

Distribution of the Insecticide

In one bin all of the October 1953 quarterly samples were analyzed separately to obtain information on the distribution pattern of the lindane in the grain mass. These data are presented in table 13. Overall, a little less than 50 percent of the application rate was recovered with the largest amounts found in the upper 5 feet of grain in the center of the bin.

Bioassay Tests

The results of the bioassay tests are presented in tables 14 and 15. These data show that there was no apparent depletion of the lindane during the observation period.

Changes in the Moisture Content

The moisture determinations of the samples drawn at monthly intervals showed that there was a continual transfer of moisture within the grain mass, but there was little change in the overall moisture content during the period of observation. The corn used in these tests was dry enough to store well, except for small amounts of spoilage in the center surface grain where moisture condensation occurred during the winter months.

Table 11.--Residues in shelled corn at intervals during storage following application of lindane at 2.7 and 5.4 p.p.m. in August 1953

Application rate and test number	Amount of lindane present in shelled corn in										Bin mean	Series mean
	1953		1954				1955			1956		
	Aug.	Oct.	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Jan.		
	Ppm	Ppm	Ppm	Ppm	Ppm	Ppm	Ppm	Ppm	Ppm	Ppm	Ppm	Ppm
2.7 p.p.m. (30 lb./ 1,000 bu. 0.5% conc.)												
1 . . .	1/	3.0	-	-	-	-	-	-	-	-	-	-
2 . . .	-	-	-	-	-	2.1	-	-	-	-	-	-
3 . . .	2.8	-	2.4	1.8	1.2	-	-	-	-	-	-	-
4 . . .	-	-	-	-	-	-	-	-	-	3.1	-	-
5 . . .	-	-	-	-	-	-	-	-	-	2.9	-	-
6 . . .	-	-	-	-	-	-	-	-	-	2.6	-	-
											-	2.4
5.4 p.p.m. (60 lb./ 1,000 bu. 0.5% conc.)												
7 . . .	-	-	-	-	-	5.3	-	-	-	-	-	-
8 . . .	2.6	3.0	2.4	2.5	0.8	4.1	1.6	0.4	3.0	-	2.3	-
9 . . .	-	-	-	-	-	-	-	-	-	5.4	-	-
10 . . .	-	-	-	-	-	-	-	-	-	4.3	-	-
											-	3.0

1/ No sample taken.

Changes in the Commercial Grade

The commercial grades taken at the beginning of the study and at quarterly intervals thereafter showed that there was no down-grading due to treatment. However, the corn in 15 of 29 bins under observation was down-graded from 1 to 5 grades because of the increase in the amount of total damage. The increase in the grade factor "Total Damage" during the storage period was due largely to moisture accumulation in the surface grain resulting in varying amounts of spoilage, chiefly in the surface corn in the center of the bin.

Table 12.--Residues in shelled corn at intervals during storage following application of lindane at 4.5 p.p.m. in August 1954

Application rate and bin number	Amount of lindane present in shelled corn in					Bin mean	Series mean
	1954	1955					
	October	January	April	July	October		
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
4.5 p.p.m. (100 lb./ 1,000 bu. of 0.25% conc.):							
1 . . .	4.8	2.6	1.2	4.4	2.5	3.1	
2	4.6	2.4	1.4	3.0	2.4	3.0	
3	5.8	2.2	2.0	3.0	2.4	3.1	
4	6.6	1.8	1.6	3.5	4.4	3.6	
5	5.3	2.4	[illegible].9	2.5	2.9	2.8	
Mean	5.4	2.3	1.4	3.3	2.9		3.1

Table 13.--Distribution of lindane in a 3,250-bushel bin of shelled corn receiving an application in August of 60 lb./1,000 bu. of 0.5-percent dust (5 p.p.m.) and sampled in October 1953

Location of sample	Amount of lindane present in shelled corn in--					
	Center of bin	North quadrant	East quadrant	South quadrant	West quadrant	Mean
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
Surface	4.0	-	-	-	-	-
Top 5 feet	6.8	1.5	2.0	2.0	2.7	3.0
Middle 5 feet . . .	4.0	2.5	2.0	3.0	2.0	2.7
Bottom 5 feet . . .	2.0	2.0	1.0	1.0	1.0	1.4
Means						
Including surface	4.2	-	-	-	-	-
Excluding surface	4.3	2.0	1.7	2.0	1.9	2.4

Table 14.--Mortality of adult rice weevils in bioassay tests with samples taken at intervals from the shelled corn treated with lindane protective dusts

Application rate and length of confinement (Weeks)	Mortality in bioassay tests following sampling 1/ in--					
	1953		1954			
	August	October	January	April	July	October
	Percent	Percent	Percent	Percent	Percent	Percent
2.7 p.p.m. (30 lb./1,000 bu. of 0.5% concentration)						
1 . . .	100	94	98	60	91	80
3 . . .	100	100	100	100	98	99
5.4 p.p.m. (60 lb./1,000 bu. of 0.5% concentration)						
1 . . .	100	100	100	99	100	99
3 . . .	100	100	100	100	100	99
4.5 p.p.m. (100 lb./1,000 bu. of 0.25% concentration)						
1 . . .	-	-	-	-	100	99
3 . . .	-	-	-	-	100	100
Untreated controls						
1 . . .	1	1	2	0	2	-
3 . . .	5	10	3	2	2	-

1/ Sampling periods correspond with those in tables 11 and 12.

COMPARATIVE ABUNDANCE OF THE SPECIES OF INSECTS

The monthly samples drawn from the bins were brought to the laboratory, screened, and the number and species of stored-grain insects were recorded. The comparative abundance of the different species is given in tables 16 and 17, expressed as percentages of the total number of insects found during 3-month periods.

Table 15.--Mortality of adult confused flour beetles and rice weevils in bioassay tests with samples taken at intervals from shelled corn treated with lindane protective dusts

Application rate and length of exposure (weeks)	Mortality of confused flour beetles					Mortality of rice weevils				
	1952	1953				1953	1954			
	December	January	March	June	August	October	February	May	August	November
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
8.1 p.p.m. (45 lb./1,000 bu. of 1% concentration)										
1	-	-	-	5	61	4	-	-	-	-
3	44	99	99	2	98	0	-	-	-	-
10.7 p.p.m. (60 lb./1,000 bu. of 1% concentration)										
1	-	-	-	100	4	100	100	100	100	100
3	100	99	99	100	100	96	100	100	100	100
Untreated controls										
1	1	-	-	1	8	-	-	-	-	-
3	-	11	-	17	6	-	-	-	-	-

Table 16.--Comparative abundance of the species of stored grain insects found in samples of wheat taken from the test bins, 1953-56

Source of samples and species of insects 1/	Proportion of species of insects in samples taken during--											Total insects found	Percent of total
	1953		1953-54				1954-55				1955-56		
	June-July	Aug.-Oct.	Nov.-Jan.	Feb.-Apr.	May-July	Aug.-Oct.	Nov.-Jan.	Feb.-Apr.	May-July	Aug.-Oct.	Nov.-Jan.		
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Number	Pct.
Treated series													
Saw-toothed grain beetle	66.7	90.7	86.7	96.7	90.3	91.7	20.9	24.3	9.0	3.6	0	1,191	71.0
Dermestidae 2/	0	7.0	8.0	3.3	9.7	8.0	79.1	75.7	91.0	96.4	100.0	476	28.2
Red flour beetle	0	0	0	0	0	0	0	0	0	0	0	4	.3
Indian-meal moth	0	2.3	0	0	0	.1	0	0	0	0	0	2	.2
Flat grain beetle 3/	0	0	0	0	0	.2	0	0	0	0	0	2	.2
Cadelle	33.3	0	0	0	0	0	0	0	0	0	0	1	.1
Total number of insects observed 4/	(3)	(43)	(75)	(30)	(72)	(1,007)	(211)	(70)	(22)	(140)	(3)	(1,676)	
No treatment--controls													
Lesser grain borer	0	3.2	8.1	51.0	0	87.3	0	0	0	0	0	637	48.0
Rice weevil	4.0	0	4.3	0	0	0	0	0	0	0	0	8	.6
Granary weevil	0	5.6	1.2	0	0	0	0	0	0	0	0	9	.7
Dermestidae 2/	0	0	.6	0	8.4	.1	0	14.3	80.0	99.5	83.4	215	16.2
Saw-toothed grain beetle	80.0	31.2	20.5	5.1	83.2	5.6	60.8	71.4	10.0	0	0	181	13.7
Flat grain beetle 3/	4.0	19.2	41.0	8.4	4.2	6.1	39.2	14.3	0	0	8.3	152	11.5
Indian-meal moth	0	34.4	10.0	0	4.2	0	0	0	10.0	.5	8.3	63	4.8
Red flour beetle	8.0	6.4	11.8	35.5	0	.9	0	0	0	0	0	56	4.2
Cadelle	4.0	0	2.5	0	0	0	0	0	0	0	0	5	.3
Total number of insects observed 4/	(25)	(125)	(161)	(59)	(24)	(676)	(28)	(14)	(10)	(192)	(12)	(1,326)	

1/ The scientific names of the insects listed herein can be found in U. S. Dept. Agr. Farmers' Bulletin 1260 (rev.), Aug. 1955.

2/ *Trogoderma* spp.

3/ Probably a complex of 3 species: *Laemophloeus pusillus* (Schönh.), *L. ferrugineus* (Steph.), and *L. turcicus* Grouv.

4/ Numbers in parentheses represent the total number of insects found during each period, and are not percentages.

Table 17.--Comparative abundance of the species of stored-grain insects found in samples of shelled c[illegible] taken from the test bins, 1953-56

Source of samples and species of insects 1/	Proportion of species of insects in samples taken during--											Total insects found	Percent of total
	1953	1953-54				1954-55				1955-56			
	Aug.-Oct.	Nov.-Jan.	Feb.-Apr.	May-July	Aug.-Oct.	Nov.-Jan.	Feb.-Apr.	May-July	Aug.-Oct.	Nov.-Jan.	Feb.		
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Number	Percent
Treated series													
Rice weevil	0	0	0	0	0.1	0	0	0	0	0	0	1	2/Tr
Saw-toothed grain beetle	45.5	92.8	100.0	98.2	98.8	97.4	100.0	99.6	99.3	99.0	96.6	4,551	96.3
Red flour beetle	6.8	6.6	0	0	.8	2.6	0	.4	.1	0	1.7	90	1.9
Angoumois grain moth	31.0	0	0	1.8	.3	0	0	0	0	0	0	48	1.1
Flat grain beetle 3/	7.4	.1	0	0	0	0	0	0	0	0	0	11	.5
Indian-meal moth	6.8	0	0	0	0	0	0	0	.5	1.0	0	17	.4
Foreign grain beetle	2.3	.4	0	0	0	0	0	0	0	0	0	6	.1
Cadelle	0	0	0	0	0	0	0	0	.1	0	0	1	2/Tr
Dermestidae 4/	0	0	0	0	0	0	0	0	0	0	1.7	1	2/Tr
Total number of insects observed 5/	(132)	(753)	(6)	(220)	(1,105)	(703)	(26)	(236)	(1,415)	(72)	(58)	(4,726)	
No treatment--controls													
Rice weevil	.8	1.0	16.7	11.6	2.3	2.3	2.1	7.4	.3	5.0	3.5	69	1.5
Granary weevil	0	0	0	0	0	0	0	0	.1	0	0	1	.1
Red flour beetle	34.8	65.4	0	4.3	28.7	65.0	34.0	0	4.6	25.5	36.8	1,535	34.0
Flat grain beetle 3/	31.8	13.8	33.2	13.1	26.6	31.1	59.6	2.5	38.3	46.0	38.6	1,294	28.7
Saw-toothed grain beetle	13.5	2.8	16.7	65.2	14.5	.2	0	82.6	54.7	6.2	18.4	1,040	23.1
Indian-meal moth	4.5	.1	16.7	0	24.8	1.0	0	4.2	1.1	9.9	1.8	210	4.7
Foreign grain beetle	6.5	11.3	0	0	0	.2	0	0	0	0	0	174	3.9
Angoumois grain moth	3.3	1.8	0	0	.4	0	0	2.5	0	0	0	57	1.2
Larger black flour beetle	2.3	1.6	16.7	0	.9	0	0	0	.3	1.2	0	50	1.1
Hairy fungus beetle	2.3	.1	0	0	.6	0	0	0	.2	0	0	31	.7
Dermestidae 4/	0	0	0	0	.6	.2	0	0	.3	6.2	.9	14	.3
Small-eyed flour beetle	0	1.6	0	0	0	0	0	0	0	0	0	15	.3
Cadelle	.2	.1	0	5.8	0	0	4.3	.8	.1	0	0	11	.2
Corn sap beetle	0	0	0	0	.6	0	0	0	0	0	0	3	.1
Two-banded fungus beetle	0	.4	0	0	0	0	0	0	0	0	0	4	.1
Total number of insects observed 5/	(1,066)	(923)	(6)	(69)	(516)	(428)	(47)	(121)	(1,137)	(81)	(114)	(4,508)	

1/ The scientific names of the insects listed herein can be found in U. S. Dept. Agr. Farmers' Bulletin 1260 (rev.) Aug. 1955.

2/ Trace--less than 0.1 percent.

3/ Probably a complex of 3 species: Laemophloeus pusillus (Schönh.), L. ferrugineus (Steph.), and L. turcicus Grouv.

4/ Trogoderma spp.

5/ Numbers in parentheses represent the total number of insects found during each period, and are not percentages.

In wheat, 8 species were noted, the most abundant in the treated wheat being the saw-toothed grain beetle followed by dermestids (chiefly Trogoderma glabrum Hbst.). These 2 species comprised 64 percent of the insects found in the treated wheat. In the untreated controls, the most abundant species was the lesser grain borer, with the dermestids (chiefly T. glabrum) second (table 16).

The saw-toothed grain beetle was the most abundant species found in the corn treated with lindane, comprising nearly 96 percent of the total number of insects recorded. In the untreated controls, the most abundant species were the red flour beetle, the flat grain beetle, and the saw-toothed grain beetle, 33, 29, and 23 percent, respectively. A total of 15 species was found in corn (table 17).

FINDINGS

Although the studies with lindane as a protective treatment have not been concluded, the following points were evident in the tests reported herein:

1. Lindane dusts, at the dosages used in these tests (up to 10 p.p.m.), failed to provide adequate protection from insect infestation.

2. The residues persisted for a long time in the grain.

3. The distribution of the lindane in the grain mass was fairly uniform.

4. In milling tests with wheat, there was evidence that the lindane had been absorbed by the endosperm and was carried into the milling fractions. However, less than 1 p.p.m. was found in the patent flour.

5. Residues in flour were not dissipated by being baked in bread; they were reduced only slightly.

6. Bioassays showed that the residues had retained their potency with aging.

7. There was but little change in overall moisture content of the grain during the period of this study.

8. There was no change in the commercial grade of the grain during the period covered by these tests.

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