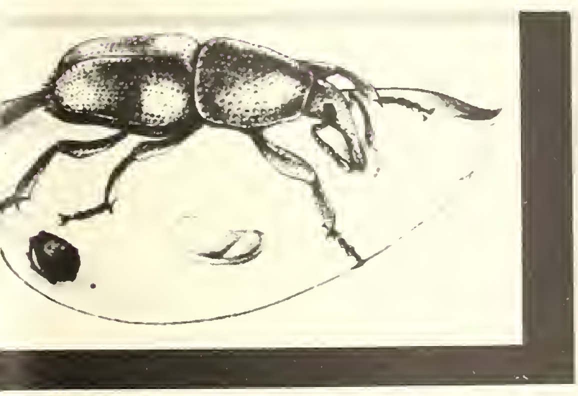
Marketing Research Report No. 272

Treatments for the Protection of Stored Southern-Grown Corn from Rice Weevil Attack
--Exploratory Tests--



Marketing Research Division
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WARNING

No tolerances have been established for the use of lindane, methoxychlor, or ryania as insecticidal applications to the entire bulk of stored grain for the prevention of insect infestation. 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, methoxychlor, or ryania protective treatments should not be used. A tolerance of 2 p. p. m. for methoxychlor in grain permits the spraying of bin walls and some surface applications, but is not high enough to cover protective treatments in the sense considered here.

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TREATMENTS FOR THE PROTECTION OF STORED SOUTHERN-GROWN CORN FROM RICE WEEVIL ATTACK---EXPLORATORY TESTS

By D. W. La Hue, Herbert Womack, and B. W. Clements, Jr.
Stored-Product Insects Laboratory
Georgia Coastal Plain Experiment Station
Tifton, Ga.[1]

SUMMARY

Exploratory studies were made at Tifton, Ga., between 1951 and 1958, on the use of lindane, malathion, methoxychlor, synergized pyrethrum, and ryania as insecticides to protect stored corn against rice weevil infestation. Results were to be used as a basis for evaluation studies on a commercial scale. Samples of treated ear corn in the husks, husked ear corn, and shelled corn were exposed for varying lengths of storage in 1-gallon jars and 5-cubic-foot drum-type bins. Protection was measured by the increase of infested ears and the increase in weevil-damaged kernels, compared to increases in untreated checks, during the selected storage periods.

Lindane protective dusts and sprays applied at dosages of 2 to 5 parts per million (p.p.m.) of lindane were highly effective in protecting husked ear corn and shelled corn for periods up to 18 months.

Malathion protective dusts and sprays were effective at dosage rates of 10 p.p.m. and above on shelled corn. Wettable powder sprays were more effective than emulsion sprays.

Methoxychlor protective dusts applied at dosages of 100 to 200 p.p.m. of methoxychlor to husked ear corn and shelled corn were effective in preventing damage or infestation, but emulsion-type sprays at the same dosages were ineffective.

Synergized pyrethrum protective dusts and sprays were not too effective at dosage rates of 0.9 to 1.42 p.p.m., but 1 inadvertent application at 36 p.p.m. of pyrethrins quickly suppressed the self-contained weevil population and finally wiped it out.

Ryania protective dusts, composed of ground ryania stems containing approximately 0.25 percent ryanodine, with and without the synergists N-propyl isome and sulfoxide, gave excellent protection against infestation and damage when applied to either husked ear corn or shelled corn at 50 to 100 pounds per 1,000 bushels.

Three materials, methoxychlor, malathion, and synergized pyrethrum, were selected for future large-scale evaluation studies. Ryania and lindane were dropped from further consideration because it appeared improbable that residue tolerances could be established in the foreseeable future in view of unresolved residue and analytical problems.

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[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. Aklee Cagle, W. O. Farmer, and Huey Hall, of the laboratory staff, assisted in many phases of these studies.

INTRODUCTION

The rice weevil, Sitophilus oryza (L.), is a serious pest of stored corn in the Southern States, from Virginia to Texas. Not many storage structures in this area are tight enough to permit fumigation, so an urgent need exists for some other means of preventing rice weevil infestation. The most promising control method other than fumigation appeared to be a protective treatment that could be applied to corn after harvest, the dual objective being to destroy the rice weevil infestation that had already been started in the field as the corn matured and to protect the corn from reinfestation from other sources during storage. Such studies were begun at Tifton, Ga., in 1951 and continued until 1958. The Tifton location was considered representative of the Southern area as far as rice weevil infestation in stored corn was concerned.

Other insects are often found in stored corn in the South, including "bran bugs," such as the flour beetles, saw-toothed grain beetle, flat grain beetle, and foreign grain beetle, and moths such as the Indian-meal moth and Angoumois grain moth. It was considered that a satisfactory protective treatment against the rice weevil would control the bran bugs. Infestation by the Indian-meal moth is confined to the surface layer of binned shelled corn, and it was considered that supplementary applications of the formulation used as a protective treatment would be necessary on the top surface. Infestation of unhusked corn, which is the form of most Southern cribbed corn, by the Angoumois grain moth is not frequent.

This report presents the results of exploratory tests made with five insecticides--lindane, malathion, methoxychlor, synergized pyrethrum, and ryania. At the start of the studies, these materials were considered as offering possibilities at application rates that would not create objectionable residues, but as these studies and others elsewhere were continued, the attitudes on acceptability of certain insecticides were altered somewhat. The experimental data on these insecticides are presented with the others, nevertheless, as a matter of record.

This study is part of a national program to improve the marketing of farm products including their protection during storage.

TECHNIQUES

Jar Test

Some of the tests with protective dusts were conducted in wide-mouthed gallon jars with samples of shelled corn weighing approximately 5 pounds. The samples were treated by placing the shelled corn and the appropriate amount of dust in a jar, capping it, and rolling and shaking it to distribute the dust. The uncapped jars were then exposed to weevil infestation in an unheated building. In some instances, as indicated in the text, weevils were confined on the samples by leaving the caps on the jars.

Drum-type Bin Test

Drum-type bins were made by rolling 2- x 8-foot sheets of masonite into cylinders and fastening the overlapping edges with roundheaded stove bolts. Each cylinder was placed upright on a 2-foot square of masonite and the shelled or ear corn was placed in it (fig. 1). Each drum contained about 5 cubic feet and could hold 4 bushels of shelled corn or 2 bushels of ear corn. These bins were placed at random on the second floor of an unheated and rather open barn on the grounds of the Georgia Coastal Plain Experiment Station, where they were exposed to a vigorous infestation of rice weevils in infested corn stored in the same building. Although the bins were tight, their open tops provided adequate opportunity for invasion of weevils from nearby sources.

BN-6654

Figure 1.--View of drum-type small bins arranged in random pattern in unheated barn.

The protective treatments were applied by two methods, both of which were considered to distribute the insecticide adequately. With one method, the sample of ear or shelled corn was placed in a tight drum, and the proper amount of protective dust added. The drum was sealed and then rolled to distribute the dust. With the second method, either protective dusts or sprays were applied to the samples as they were transferred into the drum-type bins by a belt conveyor.

Chemical Analysis of Residues

The residue analyses for samples treated with lindane, malathion, methoxychlor, and synergized pyrethrum were made by the Chemical Unit, Stored-Product Insects Section, Savannah, Ga.

Measurement of Protection

The degree of protection against insect infestation and damage provided by the various materials under test was determined by several methods. In tests with shelled corn, the original lot from which all the samples in a series were prepared was well mixed and the average percentage of weevil-damaged kernels determined. Not all weevil-damaged kernels were necessarily infested at the pre-treatment determination, but any appreciable percentage of damaged kernels was considered evidence of a vigorous infestation. In the final readings, the weevil-damaged kernels represented the total amount of weevil attack, and the damage could have been caused by several consecutive generations of weevils. The percentages of weevil-damaged kernels at the beginning and end of storage periods were sometimes supplemented by counts of the number of dead and live weevils present per unit measure at selected sampling periods.

In tests with ear corn, the percentage of weevil-damaged kernels was supplemented by counts of infested ears. At the start of storage tests, the number of infested ears was determined by evidences of weevils at the time the ears were husked--either damage or live weevils. At the end of the storage tests, the determination of infested ears was based solely on visible weevil damage. Companion counts of weevil-damaged kernels from ear corn were made by shelling a number of random-selected ears, and by sampling the shelled corn to learn the percentage of weevil-damaged kernels.

TESTS WITH LINDANE

Two series of tests (A and B) were made with lindane, the first in 1952 and the second in 1954-55.

Series A

Two lots of Dixie 18 hybrid corn of the 1951 crop were used. For the first lot, husked ear corn with a moisture content of 16 to 18 percent and with 28 percent of the ears infested and 20.4 percent of the kernels weevil-damaged was used. This was treated with 0.5-percent lindane dust in an inorganic carrier at application rates of 2 and 4 p.p.m. of lindane, and was stored for 8 months, from December 1951 until August 1952. Four replicate drum-type bins containing 2 bushels each were set up for each treatment level. After 8 months' storage, the corn was removed from the bins and the percentages of infested ears and of weevil-damaged kernels were recorded.

The second lot was shelled, and contained 23.7 percent of weevil-damaged kernels. The moisture content was not determined but was below that of the first lot. The lot was divided, and half was fumigated to destroy the self-contained weevil population. Two replicate samples of 3 bushels of each portion were dusted with 0.5 percent lindane in an inorganic carrier, at an application rate of 4 p.p.m., and each replicate was stored in a drum-type bin for 8 months, from March until November 1952. The corn was then removed from the bins and the percentage of weevil-damaged kernels determined.

The results of this series of tests are presented in table 1. In the shelled corn where the self-contained infestation was killed by fumigation, very little infestation from outside sources occurred in the 8 months, as evidenced by an increase of only 2.1 points in the percentage of weevil-damaged kernels. The unfumigated shelled corn and the ear corn showed greater increases in damaged kernels, but the degree of protection as compared with the checks was still very favorable.

Series B

Three lots of Dixie 18 hybrid shelled corn were given identical treatments in this series except that they were stored for different lengths of time, concurrent with tests in Series M (p. 18). A single-source lot of corn was used, but, as each lot was treated on a different date, the percentages of weevil-damaged kernels varied a few points.

Nine treatments were applied to replicates of 3 samples in each lot. Dusts were applied at rates of 2 and 3 p.p.m. of lindane, and 3 volumes of dust were applied at each rate by using concentrations of 0.5, 1, and 2 percent lindane in the dusts. The diluent in these dusts was an organic material, corncob flour, because other work had shown that an inorganic diluent as used in series A would cause a gritty feeling in the corn with resultant downgrading. Sprays were applied at rates of 3 and 5 p.p.m. of lindane, and at the 5 p.p.m. level the spray was applied at 2 concentrations so as to make 1 application half the volume of the other.

Table 1.--Average increase in infested ears and in weevil-damaged kernels during 8 months' storage following application of lindane dusts to husked ear corn and shelled corn

Type of corn and application rate	Pretreatment preparation	Replications	Increase in percentage of weevil-infested ears	Increase in percentage of weevil-damaged kernels
		Number	*Points*	*Points*
Ear corn:				
2 p.p.m.	--	4	14.9	12.6
3 p.p.m.	--	4	4.6	4.7
Check	--	4	62.9	40.5
Shelled corn:				
4 p.p.m.	Fumigated	2	--	2.1
	Unfumigated	2	--	12.1
Check	Fumigated	2	--	40.9
	Unfumigated	2	--	64.2

The first lot, which was stored for 9 months, from January 1955 until October 1955, had 10.52 percent weevil-damaged kernels at the start, and a moisture content of less than 13 percent; the second lot, 4.3 percent weevil-damaged kernels and 14.01 percent moisture content; the third lot, 4.6 percent damaged kernels and 13.71 percent moisture. The second lot was stored for 15 months, from October 1954 until January 1956, and the third lot for 18 months, from November 1954 until May 1956.

The lindane residues on the treated samples in the first lot after 3 months in storage were chemically analyzed to indicate the relationship between the application rate and the residue.

The results of the performance tests are presented in table 2. Both dust and spray formulations at rates of 2 and 3 p.p.m. of lindane protected the shelled corn from rice weevil infestation for periods as long as 18 months.

The residues of lindane found by chemical analysis are tabulated below. In no case did the residue exceed the application rate, and the overall average of residues was 43 percent of the applied rates.

Application rate and concentration of lindane	Residue (p.p.m.)
Dusts	
2 p.p.m.	
0.5 percent	1.30
	1.00
1 percent	1.90
	1.30
2 percent	.65
	.75
3 p.p.m.	
0.5 percent	1.30
	1.90
1 percent	1.60
	1.30
2 percent	1.30
	.75

Application rate and concentration of lindane	Residue (p.p.m.)
Sprays	
3 p.p.m.	
0.26 percent	.65
	.65
5 p.p.m.	
0.87 percent	1.90
	1.30
0.44 percent	2.00
	.75

Table 2.--Average increase in weevil-damaged kernels and in the number of live weevils per gallon during 9, 15, and 18 months' storage following application of lindane dusts and sprays at various rates; 3 replications

Type and application rate of formulation, and concentration of lindane	9 months' storage		15 months' storage		18 months' storage	
	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels
	Number	*Points*	*Number*	*Points*	*Number*	*Points*
Dusts, 2 p.p.m.:						
0.5 percent................	13.2	--	3	11.4	1	12.0
1 percent..................	6.3	--	4	13.7	1	7.0
2 percent..................	5.3	--	2	6.0	0	9.4
Dusts, 3 p.p.m.:						
0.5 percent................	4	--	1	8.4	0	3.4
1 percent..................	2.7	--	2	5.7	0	8.7
2 percent..................	2.7	--	1	4.7	0	16.7
Spray, 3 p.p.m.:						
0.26 percent (8 gal./1,000 bu.)....................	4	--	1	8.0	0	3.7
Spray, 5 p.p.m.:						
0.87 percent (4 gal./1,000 bu.)....................	4	--	0	5.7	0	8.7
0.44 percent (8 gal./1,000 bu.)....................	2.7	--	1	3.4	0	4.0
Check......................	313	--	102	65.0	135	63.0

Discussion

These tests demonstrated that lindane protective treatments, either dusts or sprays, gave excellent protection to stored ear or shelled corn, at application rates ranging from 2 to 5 p.p.m. of lindane, for periods up to 18 months.

TESTS WITH MALATHION

Two series of tests (C and D) were made with malathion, 1 in 1954-55, and the other in 1955-56.

Series C

This series paralleled series B, G, and M in that 3 lots of Dixie 18 hybrid shelled corn were given identical treatments but stored for 9, 15, and 18 months, respectively. Dusts composed of 0.25 percent malathion in wheat flour were applied at rates of 1, 2, and 5 p.p.m. of malathion; emulsion-type sprays were applied at 20 p.p.m. of malathion. The dust and spray applications were made in the same manner as described for series B.

The first lot had 10.52 percent of weevil-damaged kernels, and a moisture content of less than 13 percent. It was stored from January until October 1955. The second lot had 4.3 percent of weevil-damaged kernels and 14.01 percent moisture. It was stored from October 1954 until January 1956. The third lot had 4.6 percent of weevil-damaged kernels and 13.71 percent moisture. It was stored from November 1954 until May 1956.

The malathion residues on the treated samples in the first lot were chemically analyzed after the first 3 months in storage, to indicate the relationship between the application rate and the residue.

The results of the performance tests are given in table 3. It was demonstrated that an effective rate for dust application would need to be 3 p.p.m. of malathion or above. The emulsion spray application at 20 p.p.m. of malathion was highly effective in protecting the shelled corn.

Table 3.--Average increase in weevil-damaged kernels and in number of live weevils per gallon during 9, 15, and 18 months' storage following application of malathion dusts and sprays at various rates

Type and application rate of formulation	Replications	9 months' storage		15 months' storage		18 months' storage	
		Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels
Dust:	*Number*	*Number*	*Points*	*Number*	*Points*	*Number*	*Points*
1 p.p.m.	3	198	--	200	61.7	285	50.0
2 p.p.m.	3	21	--	230	32.7	154	20.7
3 p.p.m.	3	12	--	135	19.0	17	14.4
Spray:							
20 p.p.m.	3	3	--	1	.7	1	5.4
Check	4	313	--	102	65.3	135	63.0

The residues found on the samples of shelled corn after 3 months of storage were all less than 1 p.p.m., which at that time was the limit of sensitivity of the analytical method.

Series D

This series of tests was conducted in gallon jars, following the completion of part of series C, to define better the type of formulation and the range of effective application rates, as a prelude to large bin tests to be made later. Samples from 1 lot of Dixie 18 hybrid shelled corn, containing 5.1 percent of weevil-damaged kernels and an undetermined moisture content, were treated with dusts composed of 0.5 percent malathion in wheat flour, and with emulsion-type sprays, at rates of 5, 7.5, and 10 p.p.m. of malathion. A second lot of Dixie 18 corn from the same source was carefully handpicked to eliminate all ears showing evidence of weevil infestation or damage, then shelled and treated at the same rates as the first lot. To insure uniform distribution of the insecticide, 3-bushel lots were treated. In each instance 4 replicated samples were treated with each application rate, then emptied into drum-type bins. One week later, 1-gallon samples were taken by probing from each replicate for the jar tests, and the remainder was discarded. The samples from the first lot, which contained an average of 5.1 percent weevil-damaged kernels, were held in jars for further observation. Two hundred adult weevils were confined on each sample from the second lot, which contained no weevil-damaged kernels. The weevils were added to each jar, which was then capped. This technique was used to demonstrate the amount of protection against damage from invading insects, as compared with that against a self-contained infestation, since previous experience had indicated that protection was better against invading weevils. Records were made of the mortality of adult weevils in the samples after a selected exposure period, and also of the subsequent emergence from eggs laid during the exposure period.

The third lot was U. S. 13 hybrid corn, which is not as hard as Dixie 18 and therefore more susceptible to infestation. The percentage of weevil-damaged kernels was 6.45 at the start of the tests, and the moisture content was 14.1 percent. In this group, the relative effectiveness of dusts and wettable powder sprays was compared, and replicate samples of 3 bushels each were treated with dusts at rates of 7.5, 10, and 15 p.p.m. of malathion, and with sprays at 5, 7.5, 10, and 15 p.p.m. One-gallon samples were taken from each replicate for the jar tests. These tests were conducted between December 1955 and June 1956.

The results are presented in table 4. Two points are demonstrated by these data. First, the dust formulations produced greater mortality of adults and reduced the subsequent populations to a greater degree than did the emulsion spray. In turn, the wettable powder sprays slightly outperformed the dusts. Second, the invading weevils, as represented by the adults confined on the treated samples, were killed to a greater degree than were the self-contained infestations, and the subsequent development and emergence was less than in the self-contained infestations.

Table 4.--Percentage of dead weevils in those removed at end of first storage period, number of weevils emerging subsequently, and increase in percentage of weevil-damaged kernels following treatment of shelled corn with various formulations and rates of malathion dusts and sprays; 4 replications

Type of infestation, type of formulation, and application rate	First storage period (20 to 40 days)		Second storage period ending 100 days after treatment	Third storage period ending 160-180 days after treatment	
	Percentage of dead weevils in those removed	Increase in percentage of weevil-damaged kernels	Weevils emerging since first period	Weevils emerging since second period	Further increase in percentage of weevil-damaged kernels
Self-contained infestation:					
Dusts	*Percent*	*Points*	*Number*	*Number*	*Points*
5 p.p.m.	28.7		162.8	266.0	
7.5 p.p.m.	48.8		34.3	81.5	
10 p.p.m.	76.8		15.8	80.0	
Check	11.7		281.0	525.3	
Emulsion sprays					
5 p.p.m.	18.9		102.5	312.3	
7.5 p.p.m.	36.5		48.0	143.3	
10 p.p.m.	59.4		22.5	100.5	
Check	9.9		311.3	372.0	
200 weevils added:					
Dusts					
5 p.p.m.	80.3		18.3	41.5	
7.5 p.p.m.	86.9		8.3	19.8	
10 p.p.m.	93.9		3.8	7.5	
Check	18.4		55.3	236.5	
Emulsion sprays					
5 p.p.m.	74.5		30.5	47.0	
7.5 p.p.m.	61.3		10.3	23.5	
10 p.p.m.	84.3		5.0	9.3	
Check	15.2		44.8	219.8	
Self-contained infestation:					
Dust					
7.5 p.p.m.	54.4	3.4	153.3	87.3	0.3
10 p.p.m.	68.8	2.3	86.5	39.5	.6
15 p.p.m.	84.6	.8	27.0	18.8	.4
Check	6.1	6.1	346.0	449.3	74.6
Wettable powder spray					
5 p.p.m.	57.9	3.0	111.5	65.0	2.8
7.5 p.p.m.	74.7	.6	50.8	36.3	1.0
10 p.p.m.	84.3	0	28.3	20.8	.4
15 p.p.m.	93.6	-.3	10.0	10.0	0
Check	7.8	5.8	371.8	590.5	71.0

Discussion

The results of these series indicate that an effective application rate of malathion would be between 10 and 15 p.p.m., and that dusts or wettable powder sprays would be preferable to emulsion-type sprays.

TESTS WITH METHOXYCHLOR

Three series of tests were made with methoxychlor--Series E in 1952, Series F in 1953, and Series G in 1954-55.

Series E

Two lots of Dixie 18 hybrid corn of the 1951 crop were used in tests parallel to series A. In the first lot, husked ear corn with a moisture content of 16 to 18 percent and with 28 percent of the ears infested and 20.4 percent of the kernels weevil-damaged was treated with 10 percent methoxychlor in an inorganic diluent at application rates of 100 and 200 p.p.m. of methoxychlor, and stored from December 1951 until August 1952. Four replicate 2-bushel samples of each treatment were placed in drum-type bins and stored for the 8 months, after which the corn was removed and the percentages of infested ears and of weevil-damaged kernels were recorded.

The second lot was shelled, and had 23.7 percent of weevil-damaged kernels. The moisture content was not determined. Half was fumigated to destroy the self-contained weevil infestation. Two replicate samples of 3 bushels of each portion were dusted with 10 percent methoxychlor in an inorganic diluent, at an application rate of 200 p.p.m. of methoxychlor, and each replicate was stored in a drum-type bin for 8 months from March until November 1952. The corn was then removed from the bins and the percentage of weevil-damaged kernels determined.

The results are presented in table 5. In the shelled corn, where the self-contained infestation was killed by fumigation, very little infestation from outside sources occured in the 8 months, as evidenced by only a 2.1 increase in the percentage of weevil-damaged kernels. The unfumigated shelled corn and the ear corn showed greater increases in damaged kernels, but the degree of protection as compared with the checks was still very favorable.

Table 5.--Average increase in infested ears and in weevil-damaged kernels during 8 months' storage following application of methoxychlor dusts to husked ear corn and shelled corn

Type of corn and application rate	Pretreatment preparation	Replications	Increase in percentage of weevil-infested ears	Increase in percentage of weevil-damaged kernels
Ear Corn:		*Number*	*Points*	*Points*
100 p.p.m...........	--	4	25.8	23.2
200 p.p.m...........	--	4	18.5	12.4
Check...............	--	4	62.9	40.5
Shelled corn				
200 p.p.m...........	Fumigated	2	--	2.1
	Unfumigated	2	--	15.3
Check...............	Fumigated	2	--	40.9
	Unfumigated	2	--	64.2

Series F

Dixie 18 hybrid corn of the 1952 crop was used in this series. At the time of treatment, in July 1953, 59 percent of the ears were infested, with an average of 6.6 live adult weevils per ear.

The lot of corn was divided, and half was fumigated to destroy the self-contained infestation. Methoxychlor dusts were applied to replicate samples of unhusked ear corn, husked ear corn, and shelled corn, at various dosage rates and with various volumes of dust. Dosages of 20, 40, 60, 80, and 100 p.p.m. of methoxychlor were applied, using a 10-percent dust, and dosages of 20 and 60 p.p.m. were applied, using both a 25-percent dust and a 50-percent dust. The diluent in these dusts was an inorganic carrier. Each sample was then stored in one of the drum-type bins for 6 months, from July 1953 until

January 1954. The corn was then removed from the bins and two 1-gallon samples were taken from each bin of shelled corn for determination of the adult weevil population. The husked ear corn from each bin was shelled, thoroughly mixed, and two 1-gallon samples of the shelled corn were examined for adult weevils. Fifty ears were selected at random from each bin of unhusked ear corn and the number of ears infested with live weevils and the average number per ear were determined.

The results are given in table 6. It was evident that the weevils invading the bins from outside sources were well controlled by the dust applications, as there were fewer live weevils in bins containing corn fumigated at the start than in bins containing unfumigated corn. The weevils emerging from larvae or eggs contained within the kernels at the time the dusts were applied apparently survived in greater numbers than the invading ones. The application rates of 60 and 100 p.p.m. of methoxychlor were much more effective than was a rate of 20 p.p.m. against the emerging population, but even the 100 p.p.m. rate was not enough to give a high degree of protection. There was some indication that the 10-percent dust gave better protection than did the 25- or 50-percent dusts at the same dosage of methoxychlor, but this is not pronounced. This was undoubtedly due to better coverage because of the greater volume. The dusts did not give much protection to the unhusked ear corn. From 34 to 86 percent of the ears in fumigated lots became reinfested within 6 months in spite of the presence of the dusts. The level of infestation per ear was almost as great in the fumigated as in the unfumigated samples.

Series G

Three lots of Dixie 18 hybrid shelled corn were given identical treatments in this series, except for a difference in the length of storage, a procedure similar to that in series B and M. Ten-percent methoxychlor dusts were applied at rates of 100 and 200 p.p.m. of methoxychlor, and sprays were applied at the same rates. One lot was stored 9 months in drum-type bins, a second 15 months, and a third 18 months.

The first lot was stored for 9 months, from January 1955 until October 1955, and had 10.52 percent of weevil-damaged kernels at the start and a moisture content of less than 13 percent. The second lot had 4.1 percent weevil-damaged kernels, and 14.01 percent moisture, and was stored for 15 months, from October 1954 until January 1956. The third lot had 4.6 percent weevil-damaged kernels, and 13.71 percent moisture, and was stored for 18 months, from November 1954 until May 1956.

The methoxychlor residues on the treated samples in the first lot were chemically analyzed after the first 3 months in storage, to indicate the relationship between the application rate and the residue.

The results of the performance tests are presented in table 7. Both dust applications gave excellent protection from infestation for the 18-month period, but the spray applications gave little or no protection.

The residues of methoxychlor found by chemical analysis are tabulated below. In no case did the residue exceed the application rate, and the overall average of residues was 69 percent of the applied rates.

Application rates	Residues (p.p.m.)	Application rates	Residues (p.p.m.)
Dusts		Sprays	
100 p.p.m.	85	100 p.p.m.	70
	80		60
200 p.p.m.	170	200 p.p.m.	100
	105		125

Table 6.--Average number of weevils found per gallon of shelled corn from shelled corn and husked ear corn samples, and percentage of ears infested and weevils per ear in unhusked ear corn samples following treatment with various methoxychlor dusts and storage for 6 months

Type of corn, concentration of methoxychlor, and dosage rate	Pretreatment preparation	Replications	Adult weevils per gallon of shelled corn		Unhusked ear corn	
			Alive	Dead	Ears infested	Weevils per ear
		Number	*Number*	*Number*	*Percent*	*Number*
Shelled corn						
10-percent methoxychlor dust						
20 p.p.m.	Fumigated	3	9	149		
	Unfumigated	3	469	467		
60 p.p.m.	Fumigated	3	1	122		
	Unfumigated	3	106	415		
100 p.p.m.	Fumigated	3	1	38		
	Unfumigated	3	107	520		
25-percent methoxychlor dust						
20 p.p.m.	Fumigated	3	13	139		
	Unfumigated	3	429	1,094		
60 p.p.m.	Fumigated	3	6	100		
	Unfumigated	3	105	1,153		
50-percent methoxychlor dust						
20 p.p.m.	Fumigated	3	45	189		
	Unfumigated	3	389	832		
60 p.p.m.	Fumigated	3	1	151		
	Unfumigated	3	121	547		
Check	Fumigated	3	35	75		
	Unfumigated	2	493	120		
Husked ear corn						
10-percent methoxychlor dust						
20 p.p.m.	Fumigated	2	36	400		
	Unfumigated	2	124	233		
60 p.p.m.	Fumigated	2	3	120		
	Unfumigated	2	54	239		
100 p.p.m.	Fumigated	2	0	132		
	Unfumigated	2	9	249		
25-percent methoxychlor dust						
20 p.p.m.	Fumigated	2	194	332		
	Unfumigated	2	127	245		
60 p.p.m.	Fumigated	2	30	191		
	Unfumigated	2	82	261		
50-percent methoxychlor dust						
20 p.p.m.	Fumigated	2	33	228		
	Unfumigated	2	213	223		
60 p.p.m.	Fumigated	2	12	145		
	Unfumigated	2	302	234		
Check	Fumigated	2	102	158		
	Unfumigated	3	233	133		
Unhusked ear corn						
10-percent methoxychlor dust						
20 p.p.m.	Fumigated	2			54	5.4
	Unfumigated	2			85	7.3
60 p.p.m.	Fumigated	2			57	4.2
	Unfumigated	2			39	3.3
100 p.p.m.	Fumigated	2			34	3.7
	Unfumigated	2			43	4.3
25-percent methoxychlor dust						
20 p.p.m.	Fumigated	2			58	3.1
	Unfumigated	3			72	4.9
60 p.p.m.	Fumigated	1			66	3.8
	Unfumigated	3			76	4.8
50-percent methoxychlor dust						
20 p.p.m.	Fumigated	2			56	4.1
	Unfumigated	2			86	8.8
60 p.p.m.	Fumigated	2			16	2.2
	Unfumigated	2			48	4.3
Check	Fumigated	3			91	10.1
	Unfumigated	3			90	10.0

Table 7.--Average increase in weevil-damaged kernels and in number of live weevils per gallon during 9, 15, and 18 months' storage following application of methoxychlor dusts and sprays at various rates; 3 replications

Type and application rate of formulation	9 months' storage		15 months' storage		18 months' storage	
	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels
	Number	*Points*	*Number*	*Points*	*Number*	*Points*
Dust:						
100 p.p.m................	19	--	1	6.9	0	8.0
200 p.p.m................	12	--	1	6.6	0	2.7
Spray:						
100 p.p.m................	524	--	273	43.9	212	31.4
200 p.p.m................	808	--	558	73.9	[1] 350	72.7
Check.....................	939	--	102	65.2	135	63.0

[1] Two replications only; the third was destroyed by weevils before the test was terminated.

Discussion

These tests indicate that the effective application rate of dusts would be 100 to 200 p. p. m. of methoxychlor for shelled or husked ear corn. The failure of the spray formulation was unexpected, and sprays should not be discounted until further studies confirm or explain these results.

TESTS WITH SYNERGIZED PYRETHRUM

Three series of tests were conducted with synergized pyrethrum, in 1951-52, 1952-53, and 1954-55. These are designated as series H, I, and J.

Series H

Three lots of Dixie 18 hybrid corn of the 1951 crop were prepared as unhusked ear corn, husked ear corn, and shelled corn. Replicate samples of each lot were treated with protective pyrethrum dusts and placed in storage for 8 months to observe whether the spread of infestation from infested to uninfested unhusked and husked ears could be prevented, and whether the increase in weevil-damaged kernels in shelled corn could be suppressed.

Two-bushel samples of unhusked ear corn were treated in November 1951 and stored until July 1952. At the time of treatment, 15.6 percent of the ears were infested, as measured by the presence of live weevils within the husk or by weevil-damaged kernels, and 2.85 percent of the kernels showed weevil damage. The moisture content was between 16 and 18 percent. The corn was divided, and half was fumigated to destroy the self-contained infestation. Samples of each portion were treated with a commercially available protective dust used elsewhere in the country, composed of 0.05 percent pyrethrins and 0.8 percent piperonyl butoxide in an inorganic carrier, at the rate of 100 pounds per 1,000 bushels (1.6 ounces per bushel), which gave a dosage of 0.9 p. p. m. of pyrethrins.

Two-bushel samples of husked ear corn were treated with the same dust in December 1951 and stored until August 1952. In this instance, none of the lot was fumigated. At the time of treatment, 28 percent of the ears were infested, and 20.4 percent of the kernels were weevil-damaged. The moisture content was between 16 and 18 percent.

Three-bushel samples of shelled corn were treated in March 1952 and stored until November. At the time of treatment, 23.7 percent of the kernels showed weevil damage. The moisture content was not determined but was assumed to be less than in the ear corn lots. The lot was divided, and half was fumigated to destroy the self-contained infestation. Two dust formulations were then applied to replicate samples of each portion of the lot. One formulation was the commercially available protective dust used in the ear corn tests. The other was an experimental formulation composed of 0.08 percent pyrethrins and 1.2 percent sulfoxide in an inorganic carrier. Both were applied at the rate of 100 pounds per 1,000 bushels.

All samples were placed in the drum-type bins, where they remained undisturbed until they were removed at the end of their respective 8-month periods. The percentage of infested ears in the ear corn lots and the percentage of weevil-damaged kernels in all lots were then determined.

The results are presented in table 8. The treatment prevented reinvasion of the fumigated unhusked ear corn by weevils from outside sources, and movement from infested to noninfested ears in the unfumigated unhusked ear corn, since there was practically no increase in the number of infested ears. There was apparently some invasion from outside sources into the fumigated check sample of unhusked ears, and some movement from infested to noninfested ears. The protective dust partially suppressed weevil development in the husked ear corn, as the increase in infested ears and in weevil-damaged kernels was about one-third that in the check. There was little difference in the degree of protection to the shelled corn from the two protective dust formulations, and the increase in infested ears and weevil-damaged kernels was about two-thirds that in the check.

Table 8.--Average increase in infested ears and in weevil-damaged kernels during 8 months' storage following application of synergized pyrethrum dusts to unhusked ear corn, husked ear corn, and shelled corn

Type of corn and application rate	Pretreatment preparation	Replications	Increase in percentage of weevil-infested ears	Increase in percentage of weevil-damaged kernels
Unhusked ear corn:				
Pyrethrum-piperonyl butoxide dust		*Number*	*Points*	*Points*
0.9 p.p.m. pyrethrins	Fumigated	4	-5	1.7
	Unfumigated	4	.3	4.3
Check................	Fumigated	4	10.3	6.1
	Unfumigated	4	26.5	14.4
Husked ear corn:				
Pyrethrum-piperonyl butoxide dust				
0.9 p.p.m. pyrethrins		4	20.0	14.9
Check................		4	62.9	40.5
Shelled corn:				
Pyrethrum-piperonyl butoxide dust				
0.9 p.p.m. pyrethrins	Fumigated	2	--	21.9
	Unfumigated	2	--	39.6
Pyrethrum-sulfoxide dust				
1.42 p.p.m. pyrethrins..........	Fumigated	2	--	27.7
	Unfumigated	2	--	40.7
Check................	Fumigated	2	--	40.9
	Unfumigated	2	--	64.2

Series I

Two lots of shelled corn with a self-contained infestation were treated with pyrethrum dusts and stored in gallon jars for observation of the degree of protection against weevil damage exerted by several proposed formulations.

Three formulations were applied to the first lot early in December 1952, one of them a commercially available protective dust used elsewhere in the country, and the other two experimental formulations with a portion of the pyrethrins replaced with allethrin. The composition of the formulations was as follows (all were applied at the rate of 100 pounds per 1,000 bushels of corn):

0.05 percent pyrethrins, 0.8 percent piperonyl butoxide, in an inorganic carrier;

0.04 percent pyrethrins, 0.03 percent allethrin, 0.8 percent piperonyl butoxide, in an inorganic carrier;

0.03 percent pyrethrins, 0.06 percent allethrin, 0.8 percent piperonyl butoxide, in an inorganic carrier.

The second lot of corn, with 26.9 percent weevil-damaged kernels, was treated in November 1952. Two formulations were used; one was the commercially available protective dust containing 0.05 percent pyrethrins and 0.8 percent piperonyl butoxide in an inorganic carrier, and the second was a wettable powder that was applied as a dust, which contained 2 percent pyrethrins and 20 percent sulfoxide. Both were applied at a rate of 100 pounds per 1,000 bushels. The high concentration of pyrethrins in the wettable powder was not realized until the tests were under way.

Eight replicate samples of each treatment were prepared, then four of them were screened to remove excess dust that did not adhere to the shelled corn. The samples were examined periodically and all adult weevils removed each time until the samples were destroyed or had been in storage for 12 months. The percentage of weevil-damaged kernels was determined for the samples remaining at the 12-month period.

The results are given in table 9. The commercial protective dust applied at 0.9 p.p.m., and the experimental formulations with allethrin replacing a portion of the pyrethrins were not at a high enough concentration to suppress the development of the weevils under these conditions, and the corn samples were totally consumed at the end of 7-1/2 months of storage. On the other hand, the inadvertent high rate of application of the pyrethrin-sulfoxide formulation rapidly suppressed the weevil population and finally wiped it out.

Series J

This series paralleled series B, C, G, and M. Three lots of Dixie 18 hybrid shelled corn were given identical treatments; one was stored 9 months, one 15 months, and one 18 months. Four formulations were used. One was the commercially available protective dust used in series H and I, containing 0.05 percent pyrethrins and 0.8 percent piperonyl butoxide in an inorganic carrier, applied at the rate of 150 pounds per 1,000 bushels, giving a dosage of 1.34 p.p.m. of pyrethrins. Three protective spray formulations were applied at a dosage of 1.14 p.p.m. of pyrethrins. One was composed of 0.2 percent pyrethrins and 2 percent piperonyl butoxide applied at the rate of 4 gallons per 1,000 bushels; one was half the above concentration, applied at the rate of 8 gallons per 1,000 bushels; and the third was composed of 0.2 percent pyrethrins alone applied at the rate of 4 gallons.

The first lot was treated in January and stored until October 1955, and at the time of treatment it had 10.52 percent weevil-damaged kernels. The second lot was treated in October 1954 and stored until January 1956, and at the time of treatment it had 4.6 percent weevil-damaged kernels. The third lot was treated in November 1954 and was stored until May 1956, and at the time of treatment it had 4.6 percent weevil-damaged kernels. Three replicate samples of each treatment were stored in the drum-type bins. At the end of the respective storage periods, the corn was removed from the bins and the percentage of weevil-damaged kernels determined.

The residues of piperonyl butoxide on the treated samples in the first lot were determined after the first 3 months of storage, to indicate the relationship between the application rate and the residue.

Table 9.--Average number of adult weevils found in 5-pound samples of shelled corn treated with various synergized pyrethrum formulations, and increase in percentage of weevil-damaged kernels during the total 12-month storage period

Formulation and dosage rate per 1,000 bushels	Post-treatment handling	Replications	Average number of weevils removed after exposure of-- 4 months		5-1/2 months		10 months		12 months		Increase in percentage of weevil-damaged kernels
			Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Points*
Pyrethrum dust											
0.9 p.p.m. pyrethrins.....	Screened	4	253	337	219	45	([1])				
	Unscreened	4	237	395	184	69	([1])				
Pyrethrum-allethrin dusts											
0.71-0.53 p.p.m. pyrethrins, allethrin......	Screened	4	205	275	200	39	([1])				
	Unscreened	4	181	261	189	37	([1])				
0.53-1.06 p.p.m. pyrethrins, allethrin.....	Screened	4	203	300	199	36	([1])				
	Unscreened	4	175	380	188	38	([1])				
Check......................	Screened	4	555	16	116	17	([1])				
	Unscreened	4	611	15	135	79	([1])				
Pyrethrum-piperonyl butoxide dust											
0.9 p.p.m. pyrethrins.....	Screened	4	248	337	219	45	([1])				
	Unscreened	4	234	269	184	69	([1])				
Pyrethrum-sulfide dust											
36 p.p.m. pyrethrins......	Screened	4	11	219	4	170	1	149	1	9	-0.3
	Unscreened	4	19	213	3	176	1	214	1	9	-.9
Check......................	--	8	582	16	124	48	([1])				

[1] Samples completely consumed by the end of 7-1/2 months' storage.

The results of the performance tests are given in table 10. The protective dust performed better than did the sprays, but its effectiveness was inconsistent in that the 9- and 18-month tests indicated good protection but the 15-month one was only partially effective. The 4-gallon rate of application for the protective spray appeared more effective than the 8-gallon rate. Pyrethrum alone gave protection of the same order as the synergized pyrethrum at the same dosage of pyrethrins, but none of the sprays gave more than partial protection at this dosage.

The residues of piperonyl butoxide were found to be more than half of the applied rate, as follows:

Application rate (p.p.m.)	Residue (p.p.m.)
Dust	
13.4	8
	7
Spray	
11.4 (4-gallon rate)	4
	6
11.4 (8-gallon rate)	7
	5

Table 10.--Average increase in weevil-damaged kernels and in number of live weevils per gallon during 9, 15, and 18 months' storage following the application of pyrethrum dusts and sprays at various rates

Type and application rate of formulation	Replications	9 months' storage		15 months' storage		18 months' storage	
		Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels
	Number	*Number*	*Points*	*Number*	*Points*	*Number*	*Points*
Dust:							
1.34 p.p.m. pyrethrins....	3	55	--	244	24.1	2	9.0
Synergized pyrethrum spray:							
1.14 p.p.m. pyrethrins, 4-gallon rate...........	3	98	--	240	41.4	388	34.0
1.14 p.p.m. pyrethrins, 8-gallon rate...........	3	209	--	493	48.7	538	45.0
Pyrethrum-only spray:							
1.14 p.p.m. pyrethrins, 4-gallon rate...........	3	209	--	187	58.4	315	39.4
Check......................	4	313	--	102	64.7	135	63.0

Discussion

Tests elsewhere have demonstrated that pyrethrum protective treatments in the range of 1 to 3 p.p.m. of pyrethrins are effective because of their repellency rather than toxicity, and that repellency is not reflected in small samples but mostly under bulk storage conditions. Therefore, these tests should be considered largely in relation to effectiveness from toxicity of the treatments. On this basis, they indicate that dosage rates from 0.9 to 1.42 p.p.m. of pyrethrins are not toxic enough to give protection by this action alone against the rice weevil, but that at some point between 1.42 and 36 p.p.m., complete toxicity and effective protection can be expected.

TESTS WITH RYANIA

Three series of tests were made with ryania. Series K was limited to jar tests with shelled corn and was begun in November 1952 and continued for 12 months. Series L was begun in December 1952 as soon as the probable results from the first series began to be evident. It was divided into 2 parts, 1 consisting of drum-type bin tests with shelled corn and the other of drum-type bin tests with ear corn. Series M was started in October 1954 and continued for 18 months. It consisted of bin tests with shelled corn.

Three formulations of ryania were used in the first 2 series. One was a dust composed entirely of ground stems of ryania without any other diluent, which contained ryanodine as the active ingredient, at a strength of about 0.25 percent. The other 2 consisted of ryania dust with 3 percent synergist added, N-propyl isome in 1 formulation, and sulfoxide in the other. The third series included treatments with only the ryania dust.

Series K

A lot of shelled corn with a moisture content of 13 to 14 percent was prepared, with 26.9 percent of the kernels showing weevil damage. It was composed of mixed hybrid corn varieties harvested in the fall of 1952. Eight treatments were made in November 1952 with ryania formulations at the following rates: Ryania dust, 50, 75, and 100 pounds per 1,000 bushels; ryania-N-propyl isome dust, 75 and 100 pounds per 1,000 bushels; ryania-sulfoxide dust, 50, 75, and 100 pounds per 1,000 bushels.

Eight replicate 5-pound samples were prepared for each treatment, and each was placed in a 1-gallon wide-mouthed glass jar. Four of each 8 replicates were then screened to remove excess dust that did not adhere to the shelled corn. The samples were examined and all adult weevils removed and counted periodically until the corn had been exposed for 12 months.

The results are shown in table 11. It can be noted that the removal of the excess dust not adhering to the kernels resulted in a slightly greater increase in the percentage of weevil-damaged kernels. The synergized ryania formulations brought the original infestation under control at an earlier date, and held the increase in damaged kernels to a lower percentage than did the ryania dust. The ryania-N-propyl isome formulation appeared slightly superior to the ryania-sulfoxide formulation.

Table 11.--Average number of adult weevils found in 5-pound samples of shelled corn treated with various dosage rates of ryania formulations and increase in percentage of weevil-damaged kernels during total 12-month storage period

Formulation and dosage rate per 1,000 bushels	Post-treatment handling	Replications	Average number of weevils removed after exposures of--								Increase in percentage of weevil-damaged kernels
			4 months		5-1/2 months		10 months		12 months		
			Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	
Ryania		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Points*
50 pounds.............	Screened	4	167	47	54	200	183	208	99	13	52
	Unscreened	4	61	368	40	239	76	54	39	9	43
75 pounds.............	Screened	4	77	140	50	248	164	91	44	12	58
	Unscreened	4	34	381	34	249	41	69	19	9	33
100 pounds............	Screened	4	77	340	47	198	41	128	25	31	40
	Unscreened	4	41	294	19	275	4	218	8	43	37
Ryania-N-propyl isome											
75 pounds.............	Screened	4	46	184	6	171	1	134	2	7	21
	Unscreened	4	19	123	9	105	1	69	1	3	5
100 pounds............	Screened	4	26	59	14	133	1	126	2	13	25
	Unscreened	4	8	29	3	71	1	226	0	9	9
Ryania-sulfoxide											
50 pounds.............	Screened	4	56	274	10	284	1	94	1	7	29
	Unscreened	4	35	391	11	279	1	94	1	16	24
75 pounds.............	Screened	4	19	231	11	270	3	104	1	14	22
	Unscreened	4	34	379	11	234	2	140	1	16	16
100 pounds............	Screened	4	45	174	20	174	3	260	1	39	22
	Unscreened	4	29	125	8	199	2	303	1	39	19
Check....................	--	8	582	16	124	48	([1])	--	--	--	73

[1] The check samples were completely consumed by the end of 7-1/2 months' storage.

Series L

In this series, samples from a lot of shelled corn and from a lot of husked ear corn were dusted with each of the ryania formulations used in the preceding series, at a rate of 100 pounds per 1,000 bushels (or 1.6 ounces per bushel). The shelled corn and ear corn lots were each divided in 2, and 1 part was fumigated to destroy the self-contained weevil infestation so that any infestation would be from an outside source. The shelled corn was an early maturing hybrid variety that had been harvested in the fall of 1952 and stored as ear corn until December 1952, when it was shelled and cleaned. This lot had 21.7 percent of weevil-damaged kernels, and the moisture content was approximately 15 percent. The lot of ear corn of the hybrid variety North Carolina 27 had also been harvested in the fall of 1952 and stored unhusked until December, when it was husked preparatory to treatment. At that time, 26 percent of the ears were weevil-infested (kernels showed evidence of weevil damage, or one or more live weevils were observed), and 15.8 percent of the kernels showed weevil damage. The moisture content was 13.55 percent.

Each dusted sample of fumigated shelled corn and of unfumigated shelled corn was divided into 3 replications of 3 bushels each, each replication going into one of the drum-type bins. The fumigated and unfumigated portions of the ear corn were divided into 4 replications of 2 bushels each for each dust formulation, and likewise stored in the drum-type bins. The bins were left undisturbed for 10 months, until October 1953, when the corn was removed and examined. A sample was taken from each bin of shelled corn and the percentage of weevil-damaged kernels determined. In the ear corn samples, the percentages of infested ears and of weevil-damaged kernels were determined.

The results are presented in table 12. In the shelled corn in which the self-contained infestation was killed by fumigation, very little infestation from outside sources occurred, as evidenced by the small increase in weevil-damaged kernels. In the unfumigated samples, the increase in percentage of weevil-damaged kernels was less than 20 points, whereas practically all kernels showed weevil damage in the check. In the ear corn, the protection from insect damage was excellent.

Table 12.--Average increase in infested ears and in weevil-damaged kernels during 10 months' storage following application of protective ryania dusts at rate of 100 pounds per 1,000 bushels to husked ear corn and shelled corn

Type of corn and formulation applied	Pretreatment preparation	Replications	Increase in percentage of weevil-infested ears	Increase in percentage of weevil-damaged kernels
Shelled corn:		*Number*	*Points*	*Points*
Ryania dust...............	Fumigated	3		10.1
	Unfumigated	3		20.3
Ryania-N-propyl isome.....	Fumigated	3		8.0
	Unfumigated	3		17.9
Ryania-sulfoxide..........	Fumigated	3		5.6
	Unfumigated	3		19.5
Check....................	Fumigated	3		35.9
	Unfumigated	3		75.3
Husked ear corn:				
Ryania dust...............	Fumigated	4	2.9	-4.4
	Unfumigated	4	1.8	9.8
Ryania-N-propyl isome.....	Fumigated	4	-.2	1.5
	Unfumigated	4	1.2	4.8
Ryania-sulfoxide..........	Fumigated	4	2.3	4.1
	Unfumigated	4	2.0	6.6
Check....................	Fumigated	4	53.2	36.4
	Unfumigated	4	74.0	43.3

Series M

The third series was made with shelled corn of the hybrid variety Dixie 18, which was harvested in the early fall of 1954. It was shelled soon after harvest, dried, and cleaned. At this time, 4.6 percent of the kernels showed weevil damage, and the moisture content was 13.71 percent. Three replicate samples of 4 bushels each were dusted with ryania at the rate of 100 pounds per 1,000 bushels and stored in January 1955 for 11 months; 3 others were treated in October 1954 and stored for 15 months; and a final 3 were treated in November 1954 and stored for 18 months. When the shelled corn was removed from the bins at the end of the respective storage periods, the number of live weevils per gallon in shelled corn was determined for all lots, and the increases in the percentages of weevil-damaged kernels were determined for the 15- and 18-month storage periods.

The results are given in table 13. The degree of protection was excellent, the number of live weevils found after 11 months' storage was negligible, and the increase in percentage of weevil-damaged kernels in 15 and 18 months was very small.

Table 13.--Average increase in weevil-damaged kernels and in number of live weevils per gallon during 11, 15, and 18 months' storage following application of ryania dust at rate of 100 pounds per 1,000 bushels

Length of storage period	Replication	Live weevils per gallon of corn	Increase in percentage of weevil-damaged kernels
	Number	*Number*	*Points*
11 months.........................	3	5	--
Check..........................	3	263	--
15 months.........................	3	1	4.4
Check..........................	3	102	64.7
18 months.........................	3	0	.7
Check..........................	3	135	63.0

Discussion

It was demonstrated by these tests that ryania dusts applied to either shelled or husked ear corn gave very good protection against damage by the rice weevil during extended periods of storage. When the initial infestation at the time of treatment was low (series M, and fumigated lots in series L), the protection was excellent.

FINDINGS

The purpose of these studies was to develop information on the feasibility of using five selected insecticides--lindane, malathion, methoxychlor, synergized pyrethrum, and ryania--as protective treatments for stored corn. As a result of the exploratory studies, three materials, malathion, methoxychlor, and synergized pyrethrum, were selected for further study under commercial storage conditions, and evaluation studies were begun.

It is generally considered that an important limiting factor in establishing a residue tolerance on corn under the Miller Amendment to the Food, Drug, and Cosmetic Act will be the residue level in that portion of corn utilized as dairy feed. A tolerance for methoxychlor residues of 100 p.p.m. has been established for some forage crops; therefore, it is assumed that a tolerance of somewhat the same order may be possible on corn. The excellent results with application rates of 100 p.p.m. in these exploratory tests were encouraging enough that this insecticide was selected for practical evaluation studies.

A tolerance for residues of malathion on corn of 8 p.p.m. was recently established. The exploratory tests with malathion indicated that application rates of 10 to 15 p.p.m. are quite effective in protecting stored corn; therefore, this insecticide also was selected for evaluation studies.

Synergized pyrethrum also is acceptable from the standpoint of residue tolerances, because tolerances have been announced for pyrethrins of 3 p.p.m. and for piperonyl butoxide of 20 p.p.m. The application rates studied in these exploratory tests of 0.9 to 1.42 p.p.m. of pyrethrins were only partially effective in preventing a buildup of infestation. However, because of the small size of the samples, any effect of repellency was reduced to a minimum. In addition, the 1 application at the rate of 36 p.p.m. of pyrethrins was so positive in its effectiveness that it can be assumed that an increase in the application rate with the attendant increase in both toxicity and repellency may give excellent protection. Therefore, synergized pyrethrum also was selected for evaluation studies.

Ryania gave excellent protection against infestation, but it is doubtful that a residue tolerance can be established on stored corn for this insecticide for some time. Attempts to develop a specific chemical analysis method for the level of residues of ryanodine that would be present following effective application rates have not been successful. Also, additional data are needed on the toxicological effects of ingested ryania to evaluate the hazard of residues in the event that the level of residues can be determined. Therefore, this insecticide was not included in the evaluation studies.

The limiting factor in establishing a residue tolerance for lindane on corn is likewise the consideration of the effect of lindane in dairy feed. It has been established that a low level of lindane residue in dairy feed will result in the appearance of lindane in milk. No tolerances have been established for lindane residues in forage crops or in milk; therefore, it is unlikely that tolerances will be approved on corn. For this reason, this insecticide was not included in the evaluation studies.

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