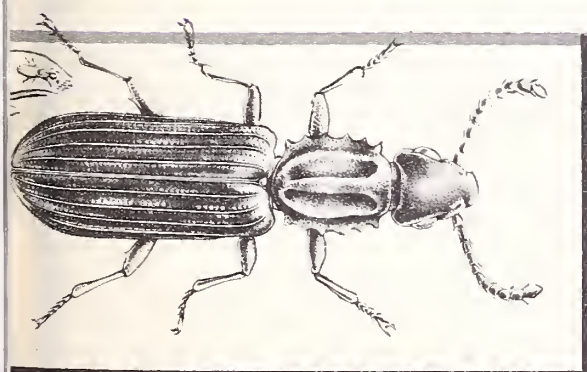
Marketing Research Report No. 322

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



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

STATUS OF TOLERANCES FOR RESIDUES OF PYRETHRUM, PIPERONYL BUTOXIDE, MGK-264, AND SULFOXIDE ON STORED WHEAT AND SHELLED CORN

Tolerances for residues of pyrethrins (the active ingredient of pyrethrum) and the synergist piperonyl butoxide on wheat and shelled corn have been established under the Miller Amendment to the Food, Drug, and Cosmetic Act. These are 3 p. p. m. (parts per million) for pyrethrins and 20 p. p. m. for piperonyl butoxide. The tolerances are sufficient to permit the use of protective pyrethrum sprays or dusts at the application rates as used in the experimental tests discussed in this report.

At the present time no tolerances have been established for residues of the other two synergists used in these tests, MGK-264 and sulfoxide, on wheat or shelled corn. The reader is cautioned that formulations containing either of these synergists should not be used until such tolerances are announced.

This report is the fourth of a group presenting results of tests with various insecticidal dusts and sprays applied to stored wheat and shelled corn for protection against insect attack.

Marketing Research Report 213 is an evaluation of methoxychlor, MRR 234 is an evaluation of lindane, and MRR 245 is an evaluation of ryania.

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.

April 195[illegible]

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ACKNOWLEDGMENTS

This report is based on research conducted by a number of individuals or groups. The performance tests were conducted by A. C. Apt, N. M. Dennis, H. E. Fearing, J. K. Quinlan, J. H. Schesser, G. H. Spitler, G. D. White, and W. K. Whitney, of the Stored-Grain Insects Laboratory, Manhattan, Kans. Studies on the chemical residues in grain were principally conducted by C. Cueto, W. E. Dale, M. F. Phillips, W. E. Priddle, and H. L. Williams, of the Stored-Product Insects Chemical Unit, Savannah, Ga. The analyses for residues in tests where MGK-264 was used as the synergist were made by the chemical laboratory of the McLaughlin Gormley King Company, Minneapolis, Minn.

Part of the research reported here was conducted with funds provided by the Commodity Credit Corporation, which also made available for experimental use a number of bins of grain at several of their bin sites.

The determinations of commercial grade were made by the Federal Grain Supervisor's offices at Kansas City, Mo., and Peoria, Ill.

SUMMARY

This report presents results of tests with various insecticidal dusts and sprays applied to stored wheat and shelled corn for protection from insect attack. The tests with synergized pyrethrum formulations made during the period September 1952 through December 1957 are summarized at this time, even though they are still in progress, because of the interest in protective dusts and sprays for the protection of stored grain.

The studies were conducted on wheat and shelled corn stored on Commodity Credit Corporation, U. S. Department of Agriculture bin sites in rectangular, wooden bins of a rated capacity of 3,200 bushels, and in standard circular metal bins of a rated capacity of 3,250 bushels. After the protective treatments were applied, the grain was sampled monthly to determine levels of insect population and moisture content, and quarterly for chemical residue analyses, bioassay tests, and commercial grade.

Various formulations of pyrethrins and a synergist were applied to wheat and shelled corn. The pyrethrins content of these formulations ranged from 0.89 to 2.50 p.p.m. (parts per million), with the synergist usually in the ratio of 1 to 10. Tests were also made with the ratio 1 to 5, with the synergist alone, and with pyrethrins alone.

Protective sprays and dusts applied at rates of 1.5 p.p.m. or higher of pyrethrins were highly effective in controlling infestations and in preventing reinfestation through 2 full summer seasons.

The residues, as determined by chemical analysis, were highest at the first reading after treatment, then fell sharply, and leveled off at a low point and persisted for periods up to 2 years. The bioassay tests showed the same trend and, after the first month, the low mortalities indicated that the residue was below the toxic level. However, the protection given the grain in the bins showed that there was a mass-repellent effect lasting a long time.

The moisture content of the samples showed a continual transfer of moisture within the grain mass, but there was little change in the average for the bin. There was no apparent effect on the performance of the protective treatment.

In the wheat used in these tests, there was no change in the commercial grade during the observation period.

In the series treated with synergized pyrethrins on a talc carrier, the corn was down-graded because the talc imparted a gritty feel to it.

A total of 13 species of stored-grain insects was found in the wheat, and a total of 19 species in the corn. The flat grain beetle, saw-toothed grain beetle, red flour beetle, and dermestids were the most abundant species observed during the period of this study.

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

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BACKGROUND AND PURPOSE OF THE WORK

Changes in grain handling and storage practices in the past few years have resulted in the storage of grain for much longer periods of time, sometimes up to 5 years. The reserve stocks of grain accumulated as a result of increased yields and the price-support programs have required new and improved methods of insect control. Emphasis is now being placed on preventive rather than curative measures.

In line with this trend, intensive studies were initiated in the fall of 1952 to explore the possibility of applying insecticides directly to stored wheat and shelled corn to prevent the development of insect infestations. The use of insecticides in this manner involves problems other than the primary one of preventing insect infestation. The fate of insecticidal residues must be studied to determine whether they will be within limits safe for the ultimate consumer, human or livestock, and whether the quality of the grain is affected by the treatment. These supplemental studies were included in the research program.

This report is the fourth of a series presenting the results of the tests with various protective treatments. The first 3 reports presented the results of tests with methoxychlor, lindane, and ryania (Marketing Research Reports 213, 234, and 245). The data presented here pertain to the studies in which synergized pyrethrum dusts and sprays were used as the protective treatment. A portion of the pyrethrum studies are still in progress, but because of the interest in protective treatments, the results as of December 1957 are given in this report. Since the data are extensive and complex, they are divided into 8 groups. The groups are subdivided into 21 series of tests with wheat and shelled corn. The formulations applied in each test are outlined below:

Group A -- Tests with shelled corn begun in 1952 at Beattie, Kans.

Series 1. A dust containing pyrethrum synergized with piperonyl butoxide, in talc.

Series 2. A dust containing pyrethrum synergized with piperonyl butoxide, in corncob flour.

Series 3. A dust containing pyrethrum synergized with sulfoxide, in ground rice hulls.

Series 4. A solution-type spray containing pyrethrum synergized with piperonyl butoxide, dissolved in a chlorinated hydrocarbon.

Series 5. An emulsion-type spray containing pyrethrum synergized with piperonyl butoxide, dispersed in water.

Group B -- Tests with shelled corn begun in 1953 at Beattie, Kans.

Series 6. An emulsion-type spray containing pyrethrum synergized with MGK-264, dispersed in water.

Series 7. A solution-type spray containing pyrethrum synergized with MGK-264, dissolved in tetrachloroethylene.

[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.

Group C -- Tests with wheat begun in 1953 at Beloit and La Crosse, Kans.

Series 8. A dust containing pyrethrum synergized with piperonyl butoxide, in pulverized wheat.

Series 9. Same as Series 4.

Series 10. Same as Series 5.

Group D -- Tests with shelled corn begun in 1953 in Illinois.

Series 11. Same as Series 4.

Series 12. A dust containing pyrethrum synergized with piperonyl butoxide, in corncob flour.

Group E -- Tests with shelled corn begun in 1953 in Missouri.

Series 13. Same as Series 4.

Series 14. Same as Series 12.

Group F -- Tests with wheat and shelled corn begun in 1954 at Clay Center, Kans.

Series 15. Same as Series 5.

Group G -- Tests with shelled corn begun in 1954 in Missouri.

Series 16. Same as Series 5.

Group H -- Tests with wheat begun in 1955 in Morris County, Kans.

Series 17. Same as Series 5.

Series 18. An emulsion-type spray containing only piperonyl butoxide, dispersed in water.

Series 19. An emulsion-type spray containing pyrethrum synergized with one-half the usual amount of piperonyl butoxide, dispersed in water.

Series 20. Same as Series 6.

Series 21. An emulsion-type spray containing only pyrethrum, dispersed in water.

TECHNIQUES

The tests were conducted in two types of bins: (1) standard USDA circular metal bins, 16 feet in height and 18 feet in diameter, with a rated capacity of 3,250 bushels; and (2) rectangular, single-walled wooden bins, 16 by 24 by 10 feet to the eaves, with gabled roofs, having a rated capacity of 3,200 bushels.

The dust applications were made either by hand as the grain was run from the auger or by a mechanical applicator attached to the tube of the auger.

The water emulsion sprays were applied with a gear pump at 40 pounds per square inch (p.s.i.) through a nozzle delivering a fan-shaped spray on the grain as it flowed into the hopper from the emptying auger. The chlorinated hydrocarbon formulation was applied with compressed air using a flow regulator to keep the pressure of 40 p.s.i. constant.

Sampling Methods

In Metal Bins

Samples were drawn from 8 places in the grain mass for monthly determinations of insect populations and moisture content. The samples were drawn with a 5-foot, 10- or 11-celled grain trier equipped with extension handles. Each sample amounted to about 500 grams of grain. The samples were taken vertically in the center of the bins 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 from the top 2 to 3 inches at the center. Each sample was bagged separately and taken to the laboratory, where it was screened to remove any insects, and the number and species of insects recorded. The screenings were returned to the sample and the moisture content determined with a dielectric moisture tester. 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.[2]

In the April, July, October, and January samplings, the pattern 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, and were then cut with a grain divider to 2 or more subsamples. One of these was analyzed for pyrethrins or synergist residues, or both. Another subsample was used in the bioassay tests. A third subsample from the sampling periods at the beginning of the test and annually thereafter or at the termination of the test was used to establish the commercial grade.

In Wooden Bins

Samples were drawn from 6 places in the grain mass with a 5-foot, 10- or 11-celled grain trier equipped with extension handles. The samples were taken vertically from the top and bottom 5 feet in the center and at a location about 3 feet from the gabled ends of the bins. These samples were handled in the same manner as for the metal bins.

Statistical Analyses

The treatments were compared 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 where it would be designated as weevily.

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

Chemical Analyses

Prior to February 1, 1956, only the residues of piperonyl butoxide were analyzed where formulations containing that synergist had been applied, and the residue of pyrethrins was assumed to be in the same ratio as in the original formulation. The residues of piperonyl butoxide were determined by the Jones-Ackerman-Webster method.[3]

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[2] In this study, 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.

For the purposes of grading, the rice and granary weevils, the lesser grain borer, and the Angoumois grain moth were classed as "weevils"; all other species of stored-grain insects were classed as bran beetles.

[3] Jones, H. A., Ackerman, H. J., and Webster, M. E. The colorimetric determination of piperonyl butoxide. Assoc. Off. Agr. Chem. Jour. 35(3):770-780, 1952.

The analyses of residues of pyrethrins made after February 1956, by the Stored-Product Insects Chemical Unit, were determined by the Williams-Dale-Sweeney Method.[4] Those made by the chemical laboratory of the McLaughlin Gormley King Co. were determined by the Schreiber-McClellan method.[5]

Formulations

Three organic carriers or diluents were used in the protective dusts as substitutes for a commonly used inorganic diluent talc. These were corncob flour, ground rice hulls, and pulverized wheat. Experience has shown that grain treated with an inorganic dust was down-graded because such dusts imparted a gritty feeling. Observations were made on the physical behavior of these diluents.

Two types of protective sprays were used. One was made from an emulsifiable concentrate of pyrethrum or synergized pyrethrum diluted with water; the other was a solution of synergized pyrethrum dissolved in a chlorinated hydrocarbon.

Three synergists were used: piperonyl butoxide (a product containing as its principal components alpha-[2-(2-butoxyethoxy)ethoxy]-4, 5-methylenedioxy-2-propyltoluene), MGK-264 (N-(2-ethylhexyl)bicyclo[2. 2. 1]-5-heptene-2, 3, dicarboximide), and sulfoxide (n-octyl sulfoxide of isosafrole).

The application rates are expressed in pounds of dust, or gallons of spray, per 1,000 bushels of grain. The dosage rates are expressed in p. p. m. of pyrethrins in order to put all treatments on an equivalent basis.

EFFECTIVENESS OF THE TREATMENTS

Group A -- Tests with Shelled Corn Begun in 1952 at Beattie, Kans.

Five formulations of pyrethrum protective treatments were used in these tests to compare the degree of protection given, as determined by observations of insect population trends. A series of bins was treated with each formulation at application rates in accordance with the recommendations of the formulators, which gave dosages of pyrethrins ranging from 0. 89 to 1. 43 p. p. m.

These series of tests were made in rectangular 3, 200-bushel wooden bins on a CCC bin site at Beattie, Kans., with 1949 crop corn, which had been stored at the site since the summer of 1950. The protective treatments were applied during September, October, and November 1952, to the shelled corn as it flowed into the hopper of the elevating auger while turning the corn from bin to bin with 2 augers (fig. 1).

Each bin was sampled monthly in the standard pattern for wooden bins described earlier, until it either reached the weevily stage, or the series was terminated in January 1956. The determinations of insect population and moisture content trends were made from the examination of these samples. A few samples were taken in selected bins for chemical analysis of residues and commercial grade.

The formulations, application rates, dosage rates, and number of bins treated were as follows:

Series 1. --Three bins of shelled corn were treated with a commercially available protective dust containing 0. 05 percent pyrethrins and 0. 8 percent piperonyl butoxide, in talc, applied at a rate of 100 pounds per 1, 000 bushels, giving a dosage rate of 0. 89 p. p. m. of pyrethrins.

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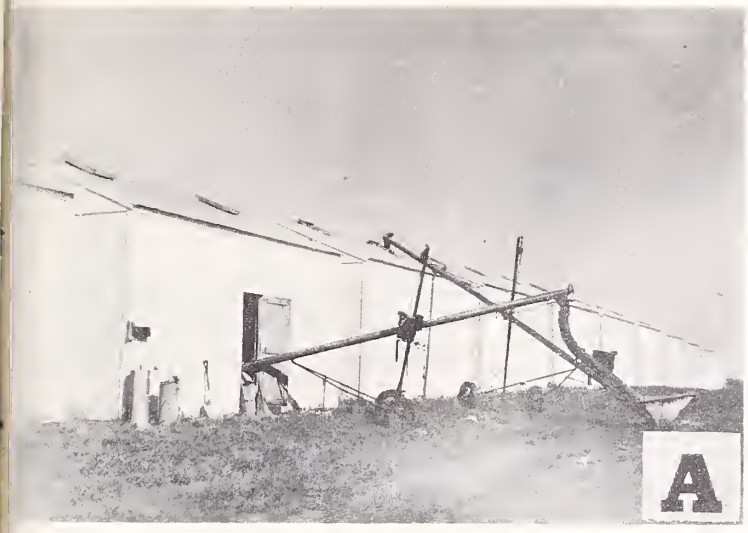
[4] Williams, H. L., Dale, W. E., and Sweeney, J. P. A new colorimetric method for pyrethrins. Assoc. Off. Agr. Chem. Jour. 39(3): 872-879, 1956.

[5] Schreiber, A. A., and McClellan, D. B. Determination of insecticide residues--analysis of flour from pyrethrum-treated cotton bags. Analyt. Chem. 24:1194-1195, 1952.



BN 7591

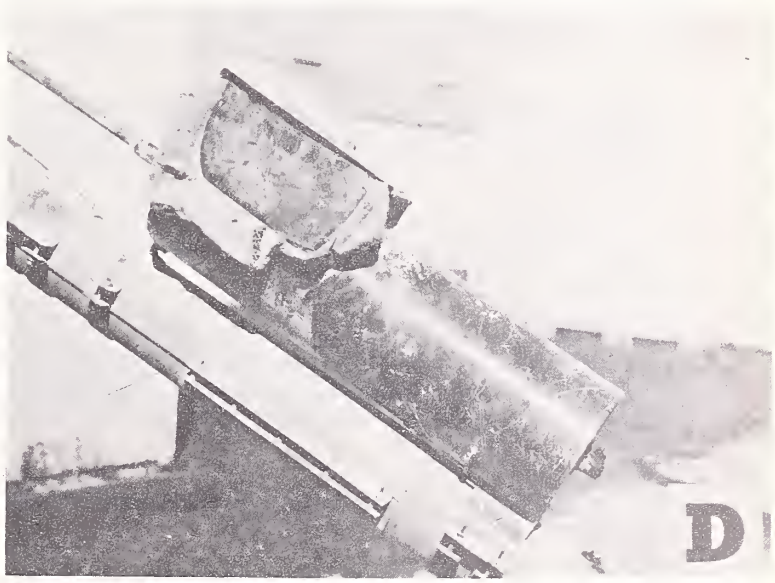
A. Applying insecticidal sprays to stored grain as it was being turned from one bin to another.

BN 7592

B. Close-up of spray nozzle for applying insecticidal spray to stored grain.

BN 7593

C. Mechanical applicator for applying insecticidal dust to grain.



BN 7594

D. Close-up of mechanical dust applicator attached to auger tube.

Figure 1.--Applying insecticidal sprays and dusts to stored grain.

Series 2. --Two bins of shelled corn were treated with an experimental protective dust containing 0.08 percent of pyrethrins and 1.1 percent piperonyl butoxide in corncob flour, one at an application rate of 75 and the other at 100 pounds per 1,000 bushels, giving dosage rates of 1.07 and 1.43 p.p.m. of pyrethrins, respectively.

Series 3. --Two bins of shelled corn were treated with an experimental protective dust containing 0.08 percent pyrethrins and 1.1 percent sulfoxide, in ground rice hulls, applied at a rate of 100 pounds per 1,000 bushels, giving a dosage rate of 1.43 p.p.m. of pyrethrins.

Series 4. --Three bins of shelled corn were treated with a commercially available protective solution-type spray containing pyrethrum and piperonyl butoxide in 1 to 10 ratio dissolved in a chlorinated hydrocarbon, applied at a rate of 2 gallons per 1,000 bushels, giving a dosage of 1.04 p.p.m. of pyrethrins.

Series 5. --Three bins of shelled corn were treated with a commercially available emulsion-type spray containing pyrethrum and piperonyl butoxide in 1 to 10 ratio diluted in water, applied at the rate of 8.33 gallons per 1,000 bushels, giving a dosage rate of 1.23 p.p.m. of pyrethrins.

Check series. --Three bins receiving no protective treatment were used as controls. The corn in these bins was not turned at the start of the test.

Insect Population Trends

The insect population trends in the treated and check bins are given in table 1. The first record given for each treated bin is the insect population present before treatment.

In Series 1, bin 1 became weevily by October 1953, but in bins 2 and 3, no infestation was recorded. This series was discontinued at that time because the corn was downgraded owing to the grittiness imparted by the treatment.

In Series 2, bin 4, which received a dosage of 1.04 p.p.m. of pyrethrins, became weevily in August 1953 and had to be fumigated. Bin 5, which received a dosage of 1.43 p.p.m. of pyrethrins, developed only minor infestation up to the time that the series was discontinued in January 1956.

In Series 3, receiving 1.43 p.p.m. of pyrethrins synergized with sulfoxide, the corn in bin 7 became weevily by July 1953, but that in bin 6 developed only minor infestation up to the time that the series was discontinued in January 1956.

In Series 4, receiving 1.04 p.p.m. of pyrethrins, the corn in bin 8 became weevily in August 1953, and that in bins 9 and 10 in September 1953. These bins were fumigated and dropped from the study.

In Series 5, receiving 1.23 p.p.m. of pyrethrins, bin 11 was inadvertently fumigated by the County ASC fumigation crew in September 1953 and was dropped from the series. However, only a light infestation had developed in this bin. Bins 12 and 13 developed only light infestations up to the time that the series was discontinued in January 1956.

In the check series, bin "A" became weevily in August 1953 and bins "B" and "C" in September 1953.

Statistical Analyses of Performance

As stated earlier, the criterion for elimination of a bin of grain from a series was whether the grain would be designated as weevily according to U. S. Grain Standards.

Table 1.--Living insects found per 1,000 grams of shelled corn in Group A tests following application of synergized pyrethrum treatments in 1952

Series, dosage rate, and bin number	1952				1953											1954												1955												1956
	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.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Series 1. Pyrethrum-piperonyl butoxide dust in talc																																							
0.89 p.p.m. of pyrethrins	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.	No.	No.	No.	No.	No.	No.	No.	No.
Bin 1	1.7	0	0	-	0	0	0	0	0	0	0	0	0	32.0																										
Bin 2	11.0	0	.4	-	0	0	0	0	0	0	0	0	0	0																										
Bin 3	33.3	0	0	-	0	0	0	0	0	0	0	0	0	0																										
Series 2. Pyrethrum-piperonyl butoxide dust, in corn cob flour																																							
1.07 p.p.m. of pyrethrins																																							
Bin 4			8.3	.4	0	0	0	0	0	.4	4.0	32.0																												
1.43 p.p.m. of pyrethrins																																							
Bin 5			11.0	0	0	0	0	0	0	.4	0	3.3	4.0	1.0	0	0	0	0	0	0.3	0	0	0	1.3	3.0	3.6	0	0.7	1.0	0	1.0	2.0	0	0	0	0	0	-	0	-	0
Series 3. Pyrethrum-sulfoxide dust, in ground rice hulls																																							
1.43 p.p.m. of pyrethrins																																							
Bin 6		9.7	0	-	0	0	0	.7	0	0	0	.7	1.5	1.0	1.3	.7	1.3	.7	1.3	.3	.7	0	0	3.6	8.0	4.7	1.3	2.0	.7	1.3	3.0	3.3	1.3	0	0	0	.3	-	0	-	0
Bin 7		13.7	0	-	0	0	0	0	0	.4	11.7																													
Series 4. Pyrethrum-piperonyl butoxide solution-type spray																																							
1.04 p.p.m. of pyrethrins																																							
Bin 8	8.0	.4	.4	0	.4	0	1.0	0	0	1.3	.7	36.7																												
Bin 9	7.3	1.0	0	0	0	0	0	0	.4	0	.4	7.7	17.7																											
Bin 10	3.7	.7	0	.4	0	0	0	0	0	.4	.4	9.7	7.7																											
Series 5. Pyrethrum-piperonyl butoxide emulsion-type spray																																							
1.23 p.p.m. of pyrethrins																																							
Bin 11	1.3	0	0	0	0	0	.4	0	0	.7	0	6.3	2.0																											
Bin 12	21.0	0	0	0	0	0	0	0	0	0	0	0	1.3	1.3	0	.4	0	0	0	0	0	0	.3	.7	2.6	3.3	5.6	.7	0	0	2.0	.7	0	.3	0	0	0	-	0	-	0
Bin 13	12.0	.7	.4	0	0	0	.7	0	0	.4	0	.7	1.0	.7	1.3	.7	1.3	0	.7	0	1.3	.7	0	1.3	.7	2.7	1.3	0	.3	.3	.3	.3	0	0	0	0	0	-	0	-	0
Check series																																								
Bin A	12.0	12.0	12.7	1.3	3.0	7.7	2.3	3.0	1.7	2.7	9.0	63.4																												
Bin B	3.0	3.0	4.0	4.7	5.1	0	1.4	1.4	1.4	0	.4	2.7	20.9																											
Bin C	2.3	2.3	1.3	1.3	.4	.7	1.4	0	1.4	.4	.4	3.0	30.0																											

The mean number of bin months of protection for a series of bins was designated as the number of bin-months of protection. The bin-months of protection for the shelled corn stored at Beattie, Kans., is given below:

Series	Treatment	Bin-months of protection
-	No treatment -- controls	10.7
1	0.89 p.p.m. (in talc carrier)	13.0
2	1.07 p.p.m. (in corncob flour)	10.0
	1.43 p.p.m.	40.0
3	1.43 p.p.m. (in ground rice hulls)	24.5
4	1.04 p.p.m. (solution-type spray)	11.3
5	1.23 p.p.m. (emulsion-type spray)	40.0

The differences between the treatments and the controls, or between treatments, were tested for significance by the method of analysis of variance. This analysis showed that the differences were not significant. The variation ratio "F" of 2.58 was less than the significant "F" value for these tests of 6.09 at the 5-percent level.

The lack of significance, even though a high degree of protection was given by the higher dosages, is due to the small number of bins included in the series.

Insecticidal Residues

The residues found in the composited samples from each bin (prepared by combining samples from 16 locations) are given in table 2. Readings from a given test were quite variable. This is assumed to be caused by a combination of uneven distribution of the pyrethrins in the grain and sampling error.

The amounts of piperonyl butoxide recovered in the first analyses in January 1953 were: Series 1, 75 percent; Series 2, 23 and 80 percent; Series 3, 31 percent; Series 4, 51 percent; Series 5, 22 percent; with an average recovery of 47 percent. It was assumed that the pyrethrins were present in the same percentages as in the original amount. The few analyses made in February 1956 indicated that the proportion of pyrethrins and piperonyl butoxide residues remained close to the 1 to 10 ratio, and demonstrated that the presence of piperonyl butoxide indicates the presence of a residue of pyrethrins.

Group B -- Tests with Shelled Corn Begun in 1953 at Beattie, Kans.

Two formulations of protective sprays in which the pyrethrum was synergized with MGK-264 were used in these tests. The tests were made in standard USDA circular metal bins of 3,250-bushels capacity at the same bin site where Group A tests were started the previous year. The corn was 1952 crop which had been delivered from farm storage to the site in August 1953. The protective treatments were applied in October by turning the corn from bin to bin. Three bins of shelled corn were treated with each formulation and 2 bins were used in the check series.

Each bin was sampled monthly in the standard pattern for metal bins described previously, to determine the insect population trends and for other purposes.

The formulations, application rates, and dosage rates were as follows:

Series 6. Three bins of shelled corn were treated with an experimental protective emulsion-type spray containing pyrethrum and MGK-264 in 1 to 10 ratio, dispersed in water, applied at the rate of 5 gallons per 1,000 bushels, giving a dosage rate of 1.32 p.p.m. of pyrethrins.

Table 2.--Residues found in samples of shelled corn taken from the treated bins in Group A, Beattie, Kans., 1952-56

Series, dosage rate, and bin number	Synergist found in--			Pyrethrins found in February 1956
	1953		1956	
	January	March	February	
Series 1. Pyrethrum-piperonyl butoxide dust, in talc				
0.89 p.p.m. of pyrethrins	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Bin 1	6.0	3.0		
Bin 2	6.0	3.0		
Bin 3	8.0	7.0		
Series 2. Pyrethrum-piperonyl butoxide dust, in corncob flour				
1.07 p.p.m. of pyrethrins				
Bin 4	2.5	2.0	10.5	<1.0
1.43 p.p.m. of pyrethrins				
Bin 5	11.5	2.0		
Series 3. Pyrethrum-sulfoxide dust, in ground rice hulls				
1.43 p.p.m. of pyrethrins				
Bin 6	2.0	23.0		
Bin 7	7.0	55.0		
Series 4. Pyrethrum-piperonyl butoxide solution-type spray				
1.04 p.p.m. of pyrethrins				
Bin 8	8.0	1.0		
Bin 9	7.0	2.0		
Bin 10	1.0	-		
Series 5. Pyrethrum-piperonyl butoxide emulsion-type spray				
1.23 p.p.m. of pyrethrins				
Bin 11	4.0	3.0		
Bin 12	21.0	1.5	3.2	<1.0
Bin 13	3.0	-	3.0	<1.0

Series 7. Three bins of shelled corn were treated with an experimental protective solution-type spray containing pyrethrum and MGK-264 in 1 to 10 ratio, dissolved in tetrachloroethylene, applied at the rate of 2 gallons per 1,000 bushels, giving a dosage rate of 1.32 p.p.m. of pyrethrins.

Check Series. Two bins of shelled corn receiving no treatment were used as controls. The corn in these bins was not turned at the start of the test.

Insect Population Trends

The insect population trends in the treated and control bins are given in table 3. In the untreated controls, the insect population in one bin had increased to the weevily level by September 1954, but the second bin carried through to August 1955 before the corn became weevily.

Table 3.--Living insects found per 1,000 grams of shelled corn in Group B tests following application of pyrethrum-MGK-264 protective sprays in 1953

Series, dosage rate, and bin number	1953			1954											1955											
	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.
Series 6. Pyrethrum-MGK-264 emulsion-type spray																											
1.32 p.p.m. of pyrethrins	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.
Bin 14	0.3	0.5	0.8	0	-	0	0	0	0	0.3	5.0	0.3	6.5	3.3	0.5	1.0	0	0	1.0	0	0	13.0	48.5				
Bin 15	0	0	8.8	0	-	.3	0	0	0	0	12.0	2.5	2.3	1.8	0	0	0	0	.3	.5	0	1.5	31.0				
Bin 16	0	0	3.5	0	-	0	0	0	0	0	0	2.5	.3	.5	0	0	0	0	0	-	0	0	0	36.0			
Series 7. Pyrethrum-MGK-264 solution-type spray																											
1.32 p.p.m. of pyrethrins																											
Bin 17	.5	0	1.0	1.0	-	0	.3	.8	1.5	3.8	1.3	.3	.3	1.8	.3	.5	.3	0	.3	0	0	0	0	13.5	15.0	-	22.8
Bin 18	0	0	1.8		-	.8	0	0	.5	1.8	1.3	.5	2.3	2.3	.5	.8	0	3.0	.5	0	.5	8.3	33.0				
Bin 19	2.0	1.8	.8	.5	-	.3	2.5	10.3	12.8	4.0	19.8	12.0	15.6	20.8	6.8	7.8	4.8	4.3	10.8	4.3	5.0	6.5	26.5				
Check series																											
Bin 20	0	0	0	0	-	0	0	.5	0	1.0	12.0	31.3															
Bin 21	.3	.3	5.5	.5	-	0	0	0	0	0	.5	.8	.3	1.3	2.0	1.3	0	0	0	0	0	1.8	29.0				

In Series 6, receiving the emulsion-type spray, light infestations developed during the first summer season of 1954, but all became weevily in August and September 1955.

In Series 7, receiving the solution-type spray, an infestation approaching the weevily level developed in one bin by November 1954, but this subsided over the winter and did not reach the weevily level until August 1955. The second bin also reached this level in August and the third in December 1955.

Statistical Analyses of Performance

As in Group A, the mean number of bin-months of protection for the 2 series in this group was computed as tabulated below:

Series	Treatment	Bin-months of protection
-	No treatment -- controls	20.5
6	1.32 p.p.m. (emulsion-type spray)	22.3
7	1.32 p.p.m. (solution-type spray)	24.0

The differences between the treatments and the controls, or between treatments, were tested for significance by the method of analysis of variance. This analysis showed that the differences were not significant. Here again, as in Group A, even though the corn was protected for nearly 2 years, the lack of significance was due to the small number of bins in the series, and also to the fact that the untreated controls failed to develop excessive insect populations.

Insecticidal Residues

The residues determined on one set of samples from Series 6 and 7, taken in January 1954, approximately 4 months after the treatments had been applied, were as follows:

Series and bin number	Residue of pyrethrins (p.p.m.)
Series 6. Pyrethrum-MGK-264 emulsion-type spray,	
Dosage rate of 1.32 p.p.m. of pyrethrins	
Bin 14	0.37
Bin 15	.50
Bin 16	.22
Mean	.36
(Residue recovered, 27 percent of dosage rate.)	
Series 7. Pyrethrum-MGK-264 solution-type spray,	
Dosage rate of 1.32 p.p.m. of pyrethrins	
Bin 17	.62
Bin 18	.41
Bin 19	.33
Mean	.44
(Residue recovered, 33 percent of dosage rate.)	

Group C -- Tests with Wheat Begun in 1953 at Beloit and LaCrosse, Kans.

One dust formulation and 2 spray formulations were used in these tests. The tests were made in standard USDA circular 3,250-bushel metal bins at CCC bin sites at Beloit and LaCrosse, Kans. The wheat was 1952 crop, which had been delivered from farm storage to the sites in May 1953. The protective treatments were applied to the wheat as it was transferred from the delivery trucks to the bins. The proper quantity of dust was applied by hand to each truckload of wheat as it was dumped into the hopper of the loading auger, and was mixed into the wheat as it was elevated into the bin. The sprays were applied to the wheat in the loading auger. A flow-meter regulated the rate of application. Twelve bins were treated with the dust formulation, 18 bins with one spray formulation, 8 bins with the second spray formulation, and 6 bins were used as checks. Each bin was sampled monthly in the standard pattern.

The formulations, application rates, and dosage rates were as follows:

Series 8. Twelve bins of wheat were treated with a commercially available protective dust containing 0.08 percent pyrethrins and 1.1 percent piperonyl butoxide, in pulverized wheat, applied at a rate of 75 pounds per 1,000 bushels, giving a dosage rate of 1.08 p.p.m. of pyrethrins.

Series 9. Eighteen bins of wheat were treated with the same commercially available solution-type protective spray as used on corn in Series 4, containing pyrethrins and piperonyl butoxide in 1 to 10 ratio dissolved in a chlorinated hydrocarbon. Six bins each were treated at application rates of 2, 3, and 4 gallons per 1,000 bushels, giving respective dosage rates of 1.08, 1.62, and 2.16 p.p.m. of pyrethrins.

Series 10. Eight bins of wheat were treated with the same commercially available emulsion-type protective spray as used on corn in Series 5, containing pyrethrins and piperonyl butoxide in 1 to 10 ratio, dispersed in water. Three bins were treated with an emulsion containing 0.1 percent pyrethrins applied at 10 gallons per 1,000 bushels, 3 bins with a 0.15 percent emulsion at 10 gallons, and 2 bins with a 0.2 percent emulsion applied at the rate of 5 gallons. These rates gave dosages of 1.36, 2.05, and 1.36 p.p.m. of pyrethrins, respectively.

Check Series. Six bins receiving no treatment were used as controls. These were loaded into the bins at the same time as the treated series.

Insect Population Trends

The insect population trends in the treated bins and in the untreated controls are given in table 4. In the untreated controls, the insect population reached the weevily level in one bin by October 1953; a second by December 1953; a third by January 1954; a fourth by February 1954; a fifth by October 1954; and the sixth carried through until August 1955 before becoming weevily.

In Series 8, receiving the commercially available protective dust, all 12 of the bins in the series developed minor infestations during the summer of 1953. Six of them became weevily in September 1954, 2 in October, one in January 1955, and the remaining 2 in August and October 1955.

In Series 9, receiving a commercially available solution-type spray, the infestations were light during the summer of 1953 in the bins treated at a rate of 1.08 p.p.m. of pyrethrins. The insect population reached the weevily level in one bin in January 1954; in one bin each in July, September, and October 1954; and in the remaining 2 in March 1955. In the bins treated at the rate of 1.62 p.p.m. of pyrethrins, the infestation in 5 bins was light during the summer of 1953, one bin becoming weevily in November 1953. A second bin was weevily by October 1954; a third by February 1955; a fourth by August 1955; and the fifth carried through to October 1955, the sixth to January 1956. In the bins treated at the rate of 2.16 p.p.m. of pyrethrins, the entire series was given excellent

Table 4.--Living insects found per 1,000 grams of wheat in Group C tests following application of synergized pyrethrum protective treatments in 1953

Series, dosage rate, and bin number	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.
Series 8. Pyrethrum-piperonyl butoxide dust, in pulverized wheat																														
1.08 p.p.m. of pyrethrins	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.
Bin 22	0	0	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0.3	7.0														
Bin 23	0	0	0	.3	0	0	0	0	0	0	0	.3	0	0	0	8.5														
Bin 24	0	0	0	.5	0	0	0	.3	0	0	0	0	0	1.8	0	8.5														
Bin 25	0	0	0	0	0	.5	0	0	0	0	0	0	0	.3	.5	0	7.5													
Bin 26	0	0	0	.5	0	0	0	0	0	0	0	0	0	0	.3	15.5														
Bin 27	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	20.3														
Bin 28	1.0	2.8	1.8	2.0	3.8	1.0	0	0	0	0	0	0	0	.3	.5	.3	9.8													
Bin 29	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	.3	0	.5	3.0	2.0	14.3										
Bin 30	0	0	0	0	0	0	0	.3	.3	0	0	0	0	0	0	0	0	0	0	0	0									
Bin 31	0	0	0	0	0	0	0	.3	2.3	0	0	0	0	0	0	0	0	.5	0	.5	3.5	2.0	0.8	0.3	3.3	27.8				
Bin 32	0	0	.3	0	0	0	0	.3	0	.8	0	0	0	2.3	3.5	16.8														
Bin 33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.8	0	0	0	0	0	0	.3	0	0	.8	0	3.8	-	58.8			
Series 9. Pyrethrum-piperonyl butoxide solution-type spray																														
1.08 p.p.m. of pyrethrins																														
Bin 34	.3	.8	.3	.3	2.8	1.8	1.5	27.0																						
Bin 35	0	0	0	1.5	.5	1.5	.3	3.0	0	0	1.5	3.0	3.5	7.0																
Bin 36	.3	0	.5	0	.5	0	.5	3.5	0	0	0	.3	.3	3.0	2.8	15.5														
Bin 37	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0	0	2.5	.5	1.3	3.3	2.3	8.3								
Bin 38	0	0	0	.3	0	.3	-	2.3	0	0	.3	0	0	0	1.3	2.3	6.5													
Bin 39	0	0	0	0	.3	0	-	.3	0	0	0	0	0	0	.3	0	2.8	2.0	2.8	3.5	3.3	10.0								
1.62 p.p.m. of pyrethrins																														
Bin 40	0	0	0	.5	0	2.0	0	0	0	0	0	0	0	0	0	0	.5	0	0	.3	0	0	0	0	0	.5	1.5	-	11.5			
Bin 41	1.3	1.8	3.8	3.0	.8	5.5																								
Bin 42	.3	2.5	3.3	3.5	1.8	.8	.3	1.5	0	0	0	0	0	0	0	0	1.0	.3	0	.3	.3	.5	0	1.0	.3	0	12.5			
Bin 43	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	0	1.3	.3	1.0	3.8	1.0	16.3									
Bin 44	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	1.5	0	0	0	0	0	0	0	0	0	.3	0	.3	-	.5	-	-	0.8
Bin 45	0	.3	0	0	1.0	0	1.8	0	.3	.5	0	0	0	0	.8	0	6.0													
2.16 p.p.m. of pyrethrins																														
Bin 46	0	0	0	0	0	0	.5	.8	0	0	.3	0	0	.8	.3	1.5	.8	0	0	.8	0	1.5	0	0	.8	1.0	12.8			
Bin 47	.3	0	0	0	.8	0	0	1.3	0	2.0	0	0	0	0	0	1.0	0	0	5.5											
Bin 48	0	0	.3	.3	0	0	0	.3	0	0	.3	0	.3	0	0	0	2.0	1.0	4.3	0	3.8	2.5	2.8	1.8	2.0	9.8				
Bin 49	.3	0	.3	0	.3	.3	-	.3	0	0	0	0	0	0	.3	.8	.8	0	0	1.0	.8	1.5	0	0	2.0	0	137.8			
Bin 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.5	0	0	0	0	0	0	.5	-	3.8	2.8	-	.8
Bin 51	0	.3	0	.3	0	0	0	0	0	0	0	0	0	0	0	.3	.5	0		.5	0	.5	1.0	.5	0	0	8.5			
Series 10. Pyrethrum-piperonyl butoxide emulsion-type spray																														
1.36 p.p.m. of pyrethrins (10-gallon rate)																														
Bin 52	0	.3	.8	10.0																										
Bin 53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	.3	0	0	0	.5	0	0	0	0	.5	2.0	-	2.5	1.0	-	.3
Bin 54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	20.0			
2.05 p.p.m. of pyrethrins																														
Bin 55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	-	0	.5	-	0
Bin 56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	5.3				
Bin 57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	-	0	0	-	0
1.36 p.p.m. of pyrethrins (5-gallon rate)																														
Bin 58	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	3.0													
Bin 59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.5	0	0	0	.3	0	-	1.3	4.8	-	2.0
Check series																														
Bin 60	0	0	0	.3	.5	.3	-	0	.5	0	0	0	0	0	.3	1.5	8.8													
Bin 61	.3	.5	0	1.3	.3	.3	-	6.3																						
Bin 62	0	0	0	.5	.5	.5	-	2.3	6.5																					
Bin 63	0	0	.8	2.0	14.5																									
Bin 64	.3	0	2.0	1.0	1.5	.8	1.0	.5	.3	0	0	.3	.8	4.5	3.5	3.0	2.8	3.5	2.5	1.0	.5	3.0	0	.5	.3	1.5	10.3			
Bin 65	1.0	4.3	1.5	2.3	2.0	1.0	5.8																							

protection through the summer of 1953 and 1954. The first bin became weevily in December 1954; a second in July 1955; the third, fourth, and fifth bins in August 1955; and the sixth carried through to January 1956 when the series was terminated.

In Series 10, receiving a commercially available emulsion-type spray, one bin of those treated at the rate of 1.36 p.p.m. of pyrethrins at the 10-gallon application rate became weevily by September 1953, a second in August 1955, and the third carried through until January 1956 when the series was discontinued. In the bins treated at the rate of 2.05 p.p.m. of pyrethrins, excellent protection was given for 2 summer seasons, 1953 and 1954, the wheat remaining virtually insect-free. One lot of wheat became weevily in August 1955 and the 2 others carried through until January 1956 when the series was discontinued.

In the bins treated at the rate of 1.36 p.p.m. of pyrethrins at the 5-gallon application rate, 1 of the 2 bins was kept virtually insect-free through the summers of 1953 and 1954, and the second bin was protected through 3 summer seasons (1953, 1954, 1955) and carried through until January 1956 when the series was discontinued.

Statistical Analyses of Performance

Group C tests were handled in the same manner as Group A. The mean number of bin-months of protection for each series was computed as tabulated below:

Series	Treatment		Bin-months of protection
-	No treatment -- controls		11.2
8	1.08 p.p.m. (commercially available dust)		17.7
9	1.08 p.p.m. (solution-type spray)		15.5
	1.62 p.p.m.		21.2
	2.16 p.p.m.		25.5
10	1.36 p.p.m. (emulsion-type spray)	10 gal./1,000 bu.	20.3
	1.36 p.p.m.	5 gal./1,000 bu.	24.0
	2.05 p.p.m.	10 gal./1,000 bu.	30.0

The differences between the treatments and the controls, or between treatments, were tested for significance by the method of analysis of variance. This analysis showed that there were significant differences. The least significant differences between means were then computed. On the basis of this calculation, there were found to be significant differences between:

The untreated controls and Series 9, 1.62 p.p.m.

The untreated controls and Series 9, 2.16 p.p.m.

The untreated controls and Series 10, 5 gal./1,000 bu., 1.36 p.p.m.

The untreated controls and Series 10, 10 gal./1,000 bu., 2.05 p.p.m.

Series 8, 1.08 p.p.m. and Series 9, 2.16 p.p.m.

Series 8, 1.08 p.p.m. and Series 10, 2.05 p.p.m.

Series 9, 1.08 p.p.m. and Series 9, 2.16 p.p.m.

Series 9, 1.08 p.p.m. and Series 10, 2.05 p.p.m.

This analysis showed that the period of protection was significantly longer in wheat treated with 1.36 p.p.m. or more than that in the untreated controls. In comparing treatments, dosages of 2.05 p.p.m. were required to produce significantly longer protection than that in the bins receiving 1.08 p.p.m.

Insecticidal Residues

The residues of piperonyl butoxide found in the composited samples from selected bins in each treated series are given in table 5. It may be noted that the consecutive readings from a given test were quite variable.

Table 5.--Residues found in samples of wheat taken from the treated bins in Group C, Beloit and La Crosse, Kans., 1953-1955

Series, dosage rate, and bin number	Piperonyl butoxide found in--								
	1953		1954				1955		
	August	Oct.	Jan.	April	July	Nov.	Jan.	April	August
Series 8. Pyrethrum-piperonyl butoxide dust									
1.08 p.p.m. of pyrethrins	*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.*
Bin 23	4.0	3.0	8.0						
Bin 24	5.0	2.0	7.0						
Bin 28	3.0	3.0	6.0						
Mean	4.0	2.7	7.0						
Series 9. Pyrethrum-piperonyl butoxide solution-type spray									
1.08 p.p.m. of pyrethrins									
Bin 35	3.0	8.0	8.0						
Bin 38	1.0	7.0	1.0						
Mean	2.0	7.5	4.5						
2.16 p.p.m. of pyrethrins									
Bin 47	6.0	19.0	6.0						
Bin 49	3.0	22.0	3.0						
Mean	4.5	20.5	4.5						
Series 10. Pyrethrum-piperonyl butoxide emulsion-type spray									
1.36 p.p.m. of pyrethrins (10 gal. rate)									
Bin 52	4.0	7.0	1.0						
Bin 53	7.0	8.0	-						
Bin 54	3.0	7.0	7.0	7.0	12.0	11.0	9.0	0.5	6.0
Mean	4.7	7.3	4.0						
2.05 p.p.m. of pyrethrins									
Bin 55	13.0	14.0	5.0						
Bin 56	10.0	12.0	11.0	10.0	17.0	12.0	12.0	1.3	7.5
Bin 57	3.0	8.0	10.0						
Mean	8.7	11.3	8.3						

The amount of piperonyl butoxide was determined, pending the development of a more sensitive method for pyrethrum analyses. The amounts of piperonyl butoxide recovered in the first analysis in August 1953 were: Series 8, 27 percent; Series 9, 18 and 20 percent; Series 10, 35 and 42 percent. In January 1954, the recoveries were: Series 8, 46 percent; Series 9, 40 and 20 percent; Series 10, 30, and 41 percent.

Analyses were continued in 2 bins until August 1955 (table 5, bins 54 and 56). These figures showed that there was little disappearance of the piperonyl butoxide during the observation period. Presuming that the degradation of pyrethrins proceeds at a similar rate, it is evident that pyrethrins under the conditions of this test are depleted very slowly.

Group D -- Tests with Shelled Corn Begun in 1953 in Illinois

A commercially available spray formulation and an experimental dust formulation at 2 concentrations each were used in these tests. The tests were made in standard USDA circular 3,250-bushel metal bins at CCC bin sites in 6 southern Illinois localities--Greenville, Bond County; Evansville, Randolph County; Jacob, Jackson County; Mt. Vernon, Jefferson County; Martinsville, Clark County; and Pinkstaff, Lawrence County. Each formulation was applied to 2 or more bins at each location.

The corn was 1952 crop, which had been cribbed during the winter and shelled just before delivery to the bin sites. The protective treatments were applied to the shelled corn as it was transferred from the delivery trucks to the bins. The sprays were applied to the corn as it was picked up by the auger, and the rate of application was regulated by a flow-meter. The proper quantity of dust was applied by hand to each truckload of shelled corn as it was dumped into the hopper of the loading auger. Twelve and 11 bins of corn were treated with 2 application rates of the spray, and 11 bins each with 2 concentrations of the dust. Nineteen bins were used as checks. Each bin was sampled monthly in the standard pattern.

The formulations, application rates, and dosage rates were as follows:

Series 11. Twenty-three bins of shelled corn were treated with the same commercially available solution-type spray as was used in Series 4 and 9, containing pyrethrins and piperonyl butoxide in 1 to 10 ratio, dissolved in a chlorinated hydrocarbon. Twelve bins were treated at an application rate of 2 gallons per 1,000 bushels, and 11 bins at 4 gallons, giving respective dosage rates of 1.16 and 2.32 p.p.m. of pyrethrins.

Series 12. Twenty-two bins of shelled corn were treated with an experimental dust formulation containing corncob flour as the diluent, applied at the rate of 75 pounds per 1,000 bushels. Eleven bins received a dust containing 0.08 and 1.10 percent of pyrethrins and piperonyl butoxide, respectively, giving a dosage of 1.07 p.p.m. of pyrethrins. Eleven more bins received a dust with double the above concentration, giving a rate of 2.14 p.p.m.

Insect Population Trends

All of the series in Illinois had to be terminated by November 1953 because much of the corn stored at these sites became unmanageable because of high moisture content and had to be sold to prevent serious deterioration. This action made it necessary to release all of the corn in the experimental series to avoid having small, scattered lots of corn to manage. The insect population trends in the treated bins and in the untreated controls are given in table 6.

In the untreated controls, the insect population in 2 bins had increased to the weevily level by August 1953; in 1 bin in September; and in 1 in October. The insect populations in the entire control series were much higher than those in the treated series.

Table 6.--Living insects found per 1,000 grams of shelled corn in Group D tests in Illinois following applications of synergized pyrethrum treatments, 1953

Series, dosage rate, and bin number	1953					
	June	July	August	September	October	November
Series 11. Pyrethrum-piperonyl butoxide solution-type spray						
1.16 p.p.m. of pyrethrins	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Bin 66	0	0	0.3	0.3	0.3	0
Bin 67	0	1.3	3.0	2.5	0	.3
Bin 68	-	-	0	0	2.3	12.0
Bin 69	0	7.8	0	0	7.4	18.5
Bin 70	0	0	3.3			
Bin 71	0	1.0	1.0	6.8	4.0	2.0
Bin 72	1.5	4.3	3.0	16.8	22.3	7.3
Bin 73	0	0	0	1.0	39.3	
Bin 74	0	0	.3	1.5	8.8	6.5
Bin 75	0	0	0	1.3	3.4	1.8
Bin 76	0	-	0	1.0		
Bin 77	0	-	0			
2.32 p.p.m. of pyrethrins						
Bin 78	0	0	0	0	0	
Bin 79	0	0	0	.3	0	0
Bin 80	0	0	0	.3	2.3	2.0
Bin 81	0	0	.3	-	0	.8
Bin 82	0	.3	.5			
Bin 83	0	.3	0	4.0	1.0	.5
Bin 84	0	.3	0	0	3.3	
Bin 85	0	0	0	0	0	0
Bin 86	0	.5	1.0	0		
Bin 87	0	0	0	0		
Bin 88	0	0	0			
Series 12. Pyrethrum-piperonyl butoxide dust in corncob flour						
1.07 p.p.m. of pyrethrins						
Bin 89	0	0	0	0	0	0
Bin 90	0	0	.3	0	0	0
Bin 91	0	.8	.3	-	3.5	1.5
Bin 92	0	0	1.3	-	12.0	16.3
Bin 93	0	0	0			
Bin 94	0	0	3.3	9.8	19.3	
Bin 95	0	.5	5.0	.8	37.4	
Bin 96	0	.5	2.0			
Bin 97	0	0	.3			
Bin 98	0	0	0			
Bin 99	0	0	0			

Continued

Table 6.--Living insects found per 1,000 grams of shelled corn in Group D tests in Illinois following applications of synergized pyrethrum treatments, 1953--Continued

Series, dosage rate, and bin number	1953					
	June	July	August	September	October	November
Series 12--Continued						
2.14 p.p.m. of pyrethrins	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Bin 100	0	0	0	0	0	
Bin 101	0	0	0	0	0	
Bin 102	0	.3	0	0	1.3	3.8
Bin 103	0	0	0	-	1.0	
Bin 104	0	0	0			
Bin 105	0	1.8	0	.5	5.0	
Bin 106	0	0	0	.3	1.8	5.8
Bin 107	0	0	0	-	2.3	1.3
Bin 108	0	0	0	0	1.0	
Bin 109	0	.3	0			
Bin 110	0	.8	0	1.3		
Check series						
Bin 111	0	4.5	6.0	12.3		
Bin 112	.5	.5	1.8	49.3		
Bin 113	1.0	4.3	22.3			
Bin 114	.5	1.8	1.5	6.8		
Bin 115	.5	2.0	4.8	2.5	14.0	20.3
Bin 116	0	11.5	7.5	-	15.0	12.3
Bin 117	0	8.3	20.0	-	17.5	16.5
Bin 118	0	1.0				
Bin 119	1.0	0	1.8			
Bin 120	.3	.3	3.5	12.3		
Bin 121	0	7.3	34.5			
Bin 122	0	3.3	39.0			
Bin 123	.3	2.3	2.0	4.8		
Bin 124	0	3.8	8.3	17.3	31.5	
Bin 125	.5	0	0			
Bin 126	0	5.0	2.3			
Bin 127	0	.8	3.5	2.0	9.5	11.3
Bin 128	0	5.5	0			
Bin 129	.3	3.0	2.5	5.5		

In Series 11, receiving the commercially available solution-type spray at the dosage rate of 1.16 p.p.m. of pyrethrins, 1 bin became weevily in October. The bins treated at the rate of 2.32 p.p.m. of pyrethrins developed only light infestations.

In Series 12, receiving the experimental dust with corncob flour diluent at a dosage rate of 1.07 p.p.m., 1 bin became weevily in October, and 2 others developed populations approaching the weevily level. The bins in the series treated at a rate of 2.14 p.p.m. of pyrethrins had only light infestations.

Statistical Analyses of Performance

This group of tests was handled in the same manner as for Group A. The mean number of bin-months of protection for each series was computed as tabulated below:

Series	Treatment	Bin-months of protection
-	No treatment -- controls	3.8
11	1.16 p.p.m. (solution-type spray)	5.2
	2.32 p.p.m.	4.9
12	1.07 p.p.m. (experimental dust)	4.5
	2.14 p.p.m.	4.8

The differences between the treatments and the controls, or between treatments, were tested for significance by the method of analysis of variance. This analysis showed that there were significant differences. The least significant differences between means were then computed. On the basis of this calculation, there were found to be significant differences between:

The untreated controls and Series 11, 1.16 p.p.m.

The untreated controls and Series 11, 2.32 p.p.m.

The untreated controls and Series 12, 2.14 p.p.m.

There were no significant differences between the means of treated series. This analysis shows that, at dosages of 1.16 p.p.m. or higher, pyrethrins synergized with piperonyl butoxide, under the conditions of these tests, gave protection during the first summer season after treatment.

Insecticidal Residues

The residues of piperonyl butoxide in the composited samples from the Illinois bins are tabulated in table 7. As stated earlier, all of the corn was removed from the sites by November 1953, therefore only one residue analysis was made. The amounts of piperonyl butoxide recovered from the July samples were: Series 11, 52 and 30 percent; Series 12, 29 and 23 percent.

Group E -- Tests with Shelled Corn Begun in 1953 in Missouri

The same commercially available spray formulations and experimental dust formulations applied to shelled corn in Illinois in Group D, were used in tests with shelled corn at CCC bin sites at Malta Bend, Marshall, and Slater in Saline County, Mo. The corn was 1952 crop, and was shelled just before delivery to the bin sites. The protective treatments were applied in the same manner as in Group D. Ten bins were treated with the spray, and 12 bins with the dust. Seven bins were used as checks. Each bin was sampled monthly in the standard pattern.

The formulations, application rates, and dosage rates were as follows:

Series 13. Ten bins of shelled corn were treated with the same commercially available solution-type spray as used in Series 4, 9, and 11, containing pyrethrins and piperonyl butoxide in 1 to 10 ratio, dissolved in a chlorinated hydrocarbon. Four bins were treated at an application rate of 2 gallons per 1,000 bushels, 2 bins at 3 gallons, and 4 bins at 4 gallons, giving respective dosage rates of 1.16, 1.74, and 2.32 p.p.m. of pyrethrins.

Table 7.--Residues found in samples of shelled corn from the treated bins in Group D, Illinois, July 1953

Series, dosage rate, and bin number	Piperonyl butoxide residue	Series, dosage rate, and bin number	Piperonyl butoxide residue
Series 11, Pyrethrum-piperonyl butoxide solution-type spray		Series 12, Pyrethrum-piperonyl butoxide dust in corn cob flour	
1.16 p.p.m. of pyrethrins	*P.p.m.*	1.07 p.p.m. of pyrethrins	*P.p.m.*
Bin 66	6	Bin 89	2
Bin 67	4	Bin 90	2
Bin 68	-	Bin 91	3
Bin 69	2	Bin 92	1
Bin 70	2	Bin 93	2
Bin 71	1		
Bin 72	1	Bin 94	8
Bin 73	2	Bin 95	3
Bin 74	7	Bin 96	3
Bin 75	3	Bin 97	5
Bin 76	10	Bin 98	1
Bin 77	30	Bin 99	1
Mean	6	Mean	3
2.32 p.p.m. of pyrethrins		2.14 p.p.m. of pyrethrins	
Bin 78	10	Bin 100	2
Bin 79	8	Bin 101	2
Bin 80	10	Bin 102	7
Bin 81	17	Bin 103	5
Bin 82	1	Bin 104	6
Bin 83	5	Bin 105	6
Bin 84	6	Bin 106	12
Bin 85	7	Bin 107	2
Bin 86	3	Bin 108	-
Bin 87	3	Bin 109	2
Bin 88	3	Bin 110	3
Mean	7	Mean	5

Series 14. Twelve bins of shelled corn were treated with the same experimental dust formulation used in Series 12, which contained corncob flour as a diluent. Six bins were treated with a dust containing 0.08 and 1.10 percent of pyrethrins and piperonyl butoxide, giving a dosage of 1.07 p.p.m., and the other 6 were treated with double the above concentration, giving a rate of 2.14 p.p.m.

In addition to the above treatments, a series of 7 bins receiving no treatments were used as controls.

Insect Population Trends

The insect populations in the treated bins and in the untreated controls are given in table 8. In the untreated controls, the insect populations in 4 bins had increased to the weevily level by October 1953; one bin in July 1954; and one bin carried through until November 1954 before developing a high level infestation. One bin (bin 155) had to be dropped from the series because of the excessively high moisture content of the corn.

In Series 13, receiving the solution-type spray at a dosage of 1.16 p.p.m. of pyrethrins, the corn in 2 bins became unmanageable because of the excessively high moisture content; one became weevily in August 1955; and one in February 1956. One of the bins treated at a rate of 1.74 p.p.m. of pyrethrins became weevily in November 1953, and the other was protected until October 1955. Of the bins treated at the rate of 2.32 p.p.m., the insect population increased to the weevily level in one bin by November 1953; one bin in March 1955; and one in October 1955. The fourth bin (bin 137) was protected until the series was terminated in December 1955.

In Series 14, receiving the experimental dust formulation at the rate of 1.08 p.p.m. of pyrethrins, the corn in one bin became weevily in March 1954; one in April 1954; one in October 1954; two in November 1954; and one in November 1955.

Of the bins treated at the rate of 2.14 p.p.m. of pyrethrins, one bin (bin 146) had to be dropped because of an objectionable odor. The other bins in the series were given excellent protection until August 1955 when one became weevily; another in October 1955; three others were protected until the series was terminated in February 1956.

Statistical Analyses of Performance

The group E tests were handled in the same way as Group A. The mean number of bin-months of protection for each series was computed as tabulated below:

Series	Treatment	Bin-months of protection
-	No treatment--controls	5.1
13	1.16 p.p.m. (solution-type spray)	27.0
	1.74 p.p.m.	14.5
	2.32 p.p.m.	19.0
14	1.07 p.p.m. (experimental dust)	13.7
	2.14 p.p.m.	28.6

The differences between the treatments and the controls, or between treatments, were tested for significance by the method of the analysis of variance. This analysis showed that there were significant differences. The least significant differences between means were then computed. On the basis of this calculation, there were found to be significant differences between:

The untreated controls and Series 13, 2.32 p.p.m.

The untreated controls and Series 13, 1.16 p.p.m.

Table 8.--Living insects found per 1,000 grams of shelled corn in Group E tests following application of synergized pyrethrum protective treatments in Missouri, 1953

Series, dosage rate, and bin number	1953					1954											1955												1956	
	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.	Feb.
Series 13. Pyrethrum-piperonyl butoxide solution-type spray																														
1.16 p.p.m. of pyrethrins	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.
Bin 130	0	1.5	1.3	2.3	2.0	-	0.5	0	0	0.3	0.5	0	7.8	3.8	0.3	2.5	3.8	0	0.8	0.3	0	0	0.3	1.0	4.8					
Bin 131	0	1.5	1.3	2.3	1.0	-	.3	0	0	0	0	0	1.5	1.0	1.8	0	2.0	.5	0	0	0	0	0	0	5.0	10.8	1.8	-	6.0	-	110.0
Bin 132	0	0	1.8	12.0	1.0	-	.5	0																						
Bin 133	0	0	.8	2.8	9.5	-	15.3	7.0																						
1.74 p.p.m. of pyrethrins																														
Bin 134	0	1.3	7.8	30.0																										
Bin 135	0	.5	5.0	5.8	2.5	-	0	.3	0	0	0	0	.5	0	.3	.3	1.5	.3	0	0	0	0	0	0	.5	2.5	2.5			
2.32 p.p.m. of pyrethrins																														
Bin 136	.3	0	0	5.5	0	-	0	0	0	0	0	0	0	.8	.5	.8	0	0	0	0	0	0	.3	0	4.3	11.5	21.8			
Bin 137	0	.3	3.5	2.3	2.0	-	0	0	0	.5	.3	0	.5	2.3	1.8	1.0	.5	0	0	0	.3	0	0	.8	2.0	.8	2.0	-	5.0		
Bin 138	0	0	1.3	52.5																										
Bin 139	0	0	0	.5	0	-	.5	0	.5	0	0	0	0	1.8	3.0	2.0	.3	2.5	2.0	29.8										
Series 14. Pyrethrum-piperonyl butoxide dust in corncob flour																														
1.07 p.p.m. of pyrethrins																														
Bin 140	.3	.5	5.5	21.3	14.3	-	13.5	.8	0	.5	.5	.3	6.8	5.5	3.8	5.8														
Bin 141	0	.3	.5	2.8	.8	-	8.0	13.8																						
Bin 142	0	.8	.5	.8	0	-	0	0	0	0	0	0	2.5	1.3	.3	1.3	1.3	3.0	0	1.3	.8	0	0	.3	0	5.6	7.8	21.0		
Bin 143	0	0	0	0	0	-	0	0	8.8																					
Bin 144	0	.8	1.0	0	0	-	0	0	0	2.3	.5	3.3	11.5	16.3	14.8															
Bin 145	0	.3	1.8	3.8	3.3	-	0	0	0	.3	.3	0	2.0	8.3	13.5	26.8														
2.14 p.p.m. of pyrethrins																														
Bin 146	0	0	.5	2.3	0	-	0	1.5	.8																					
Bin 147	0	1.8	.3	3.8	1.0	-	0	0	0	0	0	0	.8	.5	.8	.8	.3	0	0	0	0	0	0	0	.5	.3	1.8	-	.5	-	2.0
Bin 148	0	0	.3	2.8	.5	-	0	0	0	0	0	0	.5	.8	1.5	1.5	.5	0	0	0	0	0	.5	0	0	4.3	.5	-	1.3	-	1.5
Bin 149	0	0	.3	2.3	2.3	-	0	0	0	0	0	.3	0	.3	.5	.8	.5	1.0	2.0	.3	0	0	.5	2.3	3.0					
Bin 150	0	0	.3	.3	0	-	0	0	0	.3	0	0	0	.5	.3	.3	.5	0	0	0	0	0	.5	.3	4.3	1.0	4.3			
Bin 151	0	0	.8	0	1.0	-	0	0	0	0	0	0	.3	0	.8	0	0	.3	0	0	0	0	0	0	.5	.3	.3	-	.5	-	0
Check series																														
Bin 152	1.3	10.8	32.3																											
Bin 153	1.8	14.3	92.8																											
Bin 154	.3	3.5	49.8																											
Bin 155	0	8.0	17.5	9.8	0																									
Bin 156	2.0	12.0	4.5	2.8	1.0	-	.3	0	.5	1.5	1.5	13.3																		
Bin 157	0	8.3	37.5																											
Bin 158	.3	5.0	8.0	1.8	4.3	-	.5	0	.3	.3	.3	0	6.8	8.8	3.5	20.8	.8	.3												

The untreated controls and Series 14, 2.14 p.p.m.

The untreated controls and Series 14, 1.07 p.p.m.

Series 13, 1.74 p.p.m. and Series 14, 2.14 p.p.m.

Series 13, 1.16 p.p.m. and Series 14, 1.07 p.p.m.

Series 14, 1.07 p.p.m. and Series 14, 2.14 p.p.m.

This analysis showed that the insect populations in shelled corn were significantly lower in bins treated with 1.07 p.p.m. than those in the untreated controls. In comparing treatments, there were no significant differences in Series 13. There were, however, significant differences between Series 13 and 14, and also between the high and low dosages in Series 14.

Insecticidal Residues

The residues of piperonyl butoxide found in the composited samples from selected bins in each treated series are given in table 9. There were wide variations in consecutive analyses from a given test, and also between tests.

The amount of piperonyl butoxide was determined, pending the development of a more sensitive method for detection of pyrethrins, in all except the January 1956 analyses when both pyrethrins and piperonyl butoxide were determined.

The amounts of piperonyl butoxide recovered in the first analyses in August 1953 soon after treatment were: Series 13, 11.6 p.p.m. applied, 52 percent recovered; 17.4 p.p.m. applied, 18 percent recovered; and 23.2 p.p.m. applied, 33 percent recovered. In Series 14, the recoveries were: 14.7 p.p.m. applied, 27 percent recovered; and 29.4 p.p.m. applied, 22 percent recovered.

The analyses were continued in one bin until January 1956 (bin 148, table 9). There was little change in the piperonyl butoxide residues during the observation period. On the presumption that the degradation of pyrethrins proceeds at a similar rate, then the pyrethrins were depleted very slowly under the conditions of this test.

Group F -- Tests with Wheat and Shelled Corn Begun in 1954 at Clay Center, Kans.

An emulsion-type spray was used in this series, prepared from an experimental so-called oil-free emulsifiable concentrate of pyrethrins and piperonyl butoxide. This spray was applied to 3 bins each of wheat and shelled corn at a CCC bin site at Clay Center, Kans. The wheat was of 1953 crop delivered to the bin site from farm storage in April 1954. The corn was also of 1953 crop and had been shelled just prior to delivery to the bin site in September 1954. The grain was treated as it was turned from one bin to another, the insecticide being applied as the grain ran into the hopper of the loading auger. The bins were sampled monthly in the standard pattern.

The formulation, application rate, and dosage rates were as follows:

Series 15. Three bins of wheat and three of shelled corn were treated with a dilute spray containing 0.32 percent pyrethrins at the rate of 4 gallons per 1,000 bushels, giving dosage rates of 1.56 p.p.m. in the wheat and 1.67 p.p.m. in the corn. The emulsifiable concentrate contained 6 percent pyrethrins, 60 percent piperonyl butoxide, 20 percent emulsifier, and 15 percent oil and inert, by weight. One bin each of wheat and shelled corn was used as a check.

Insect Population Trends

The insect population trends in the treated bins and in the untreated controls are given in table 10. In the untreated controls, the wheat became weevily within a month after the series was started, but the shelled corn did not become weevily until October 1955.

Table 9.--Residues of piperonyl butoxide found in samples of shelled corn from the treated bins in Group E, Missouri, 1953-1956

Series, dosage rate, and bin number	Piperonyl butoxide found in--										
	1953		1954				1955				1956
	Aug.	Oct.	Jan.	Apr.	July	Nov.	Jan.	Apr.	Aug.	Oct.	Jan.
Series 13. Pyrethrum-piperonyl butoxide solution-type spray											
1.16 p.p.m. of pyrethrins	*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.*
Bin 130.....	3.0	5.0	5.0								
Bin 132.....	7.0										
Bin 133.....	8.0										
1.74 p.p.m. of pyrethrins											
Bin 135.....	3.0										
2.32 p.p.m. of pyrethrins											
Bin 136.....	11.0										
Bin 137.....	4.0										
Bin 138.....	8.0	8.0	8.0								
Series 14. Pyrethrum-piperonyl butoxide dust in corncob flour											
1.07 p.p.m. of pyrethrins											
Bin 140.....	7.0										
Bin 141.....	3.0	2.0	9.0								
Bin 142.....	4.0										
Bin 143.....		3.0	8.0								
Bin 144.....	3.0	2.0	8.0								
Bin 145.....	3.0										
2.14 p.p.m. of pyrethrins											
Bin 146.....	7.0										
Bin 147.....	8.0										[1]15.1
Bin 148.....	8.0	2.0	25.0	10.0	16.0	17.0	12.0	6.3	5.0	5.6	[1]16.7
Bin 149.....	6.0										
Bin 150.....	4.0	2.0	9.0								
Bin 151.....	6.0	2.0	13.0								[1] 8.9

[1] These samples also analyzed for pyrethrins residues, which were found to be less than 1.0 p.p.m. for each bin.

The treated wheat became weevily before the end of 1954: one bin in October, one in November, and one in December. The corn was afforded much better protection, none of the bins becoming weevily up to the time the series was discontinued in January 1956.

Table 10.--Living insects found per 1,000 grams of grain in Group F tests at Clay Center, Kans., following application of synergized pyrethrum protective treatments in 1954

Series number, formulation, dosage rate, and bin number	1954					1955												1956
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Series 15. Pyrethrum-piperonyl butoxide oil-free emulsion-type spray																		
Wheat																		
1.56 p.p.m. of pyrethrins	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Bin 159.....	8.5	0.3	0	0	4.8													
Bin 160.....	2.5	.3	8.3															
Bin 161.....	3.3	.5	.8	9.3														
Corn																		
1.67 p.p.m. of pyrethrins																		
Bin 163.....		.3	1.8	.5	.3	.3	0	0	0	0.3	0	0	.5	-	1.8	-	4.5	1.8
Bin 164.....		2.8	.3	.3	0	0	0	0	0	0	0	0	0	-	.8	-	.5	.5
Bin 165.....		2.5	.3	.3	.3	0	0	0	0	0	0	0	.3	-	.8	-	.3	.3
Check series																		
Bin 162 (wheat)..	3.8	5.0																
Bin 166 (corn)...		3.3	1.5	10.0	8.3	2.3	6.0	1.0	4.0	.5	.5	10.3	16.3	-	19.3			

Statistical Analysis of Performance

This group of tests could not be analyzed statistically because of the small number of bins in the series. However, the mean number of bin-months of protection for the series was computed as tabulated below:

Series	Kind of grain	Treatment	Bin-months of protection
-	Wheat	No treatment--controls	1
-	Corn	No treatment--controls	14
15	Wheat	1.56 p.p.m.	3
15	Corn	1.67 p.p.m.	17

The reasons for the poor showing of the pyrethrins in the bins of wheat are not clear, but may have been due in part to the time of loading the bins. The treatment of the corn in September, when the outdoor temperatures are enough lower to retard insect population increases, may have been a factor in the apparently better protection of the corn over the wheat.

Insecticidal Residues

Only one analysis of residues was made from the Series 15 tests. Wheat from bin 159 was analyzed in January 1956 for residues of both pyrethrins and piperonyl butoxide, which were found to be 0.5 p.p.m. pyrethrins and 9.0 p.p.m. of piperonyl butoxide. The application rate for this test was 1.56 p.p.m. of pyrethrins and 15.6 p.p.m. of piperonyl butoxide. On the basis of this single test, the recovery after aging for 18 months was 32 percent of pyrethrins and 58 percent of piperonyl butoxide.

Group G -- Tests with Shelled Corn Begun in 1954 in Missouri

A commercially available emulsion-type spray was used in these tests. The spray was applied to a single series of 5 bins of shelled corn at a CCC bin site at Marshall, Saline County, Mo. The corn was 1953 crop which was shelled and delivered to the bin site in the summer of 1954. The spray was applied to the corn as it was turned from one bin to another, as it ran into the hopper of the loading auger. The bins were sampled monthly in the usual pattern.

The formulation, application rate, and dosage rate were as follows:

Series 16. Five bins of shelled corn were treated with a commercially available emulsion-type spray containing pyrethrins and piperonyl butoxide in 1 to 10 ratio, at an application rate of 5 gallons per 1,000 bushels, giving a dosage of 1.67 p.p.m. of pyrethrins. A series of 6 bins was used as checks.

Insect Population Trends

The insect populations in the treated bins and also in the untreated controls are given in table 11. In the untreated controls all of the bins were infested but the insect populations did not rise to the weevily level in any of the bins until September 1955 when 2 bins became weevily; another developed excessive Indian-meal moth infestations by October 1956; the remaining 2 bins, while developing populations of 16 to 19 insects per 1,000 grams, did not reach the weevily level and were continued through the 1957 season.

In Series 16, all 5 treated lots of corn remained virtually free from insect infestation throughout the observation period.

Table 11.--Living insects found per 1,000 grams of shelled corn in Group G tests, following application of synergized pyrethrum protective treatments in Missouri, 1954

Series, dosage rate, and bin number	1954					1955											1956											1957											
	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.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Series 16. Pyrethrum-piperonyl butoxide emulsion-type spray 1.67 p.p.m. of pyrethrins	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.	No.	No.	No.	No.	No.	No.	No.	No.
Bin 167.....	0.5	2.3	0	0.3	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Bin 168.....	1.8	1.8	0	.3	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	.3	0	0		0	0	0	0	0	0	0	0	0	0	0	0
Bin 169.....	1.0	1.8	.3	.5	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	.3	0	0	.5	.3	0	0	0	0	0	0	0	0	0	.3	.8	.3
Bin 170.....	.5	2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	.3	.3	0	.3	.3
Bin 171.....	1.8	1.3	.3	.5	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	.3	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Check series																																								
Bin 172.....	2.3	6.5	3.5	5.0	22.5	3.5	.8	1.0	0	0	1.3	1.3	9.3	18.5	3.5	-	3.5	-	1.3	3.8	.8	1.3	4.0	16.0	0	0	.5	0	.3	0	0	0	-	0	0	0	.3	1.0	.3	2.3	2.0
Bin 173.....	1.8	5.8	2.8	2.0	.5	.3	0	.3	.5	0	1.3	2.0	13.3	10.8	9.0	-	1.0	-	2.0	0	0	0	.3	4.5	19.3	8.3	11.3														
Bin 174.....	0	1.3	.8	2.8	0	0	0	0	0	0	0	.8	5.0	30.5																											
Bin 175.....	.8	4.8	1.8	1.3	2.5	3.5	1.0	.3	1.0	0	0	.5	6.0	9.8	1.3	-	3.5	-	4.5	2.0	2.0	0	4.8	16.8	0	.7	1.8	.5	3.0	2.0	0	0	-	0	0	0	.5	0	0	1.0	1.0
Bin 176.....	6.5	6.8	5.3	7.0	4.5	2.3	5.5	.5	0	0	0	1.3	13.0	23.5	4.0	-	2.0	-	127.0																							
Bin 177.....	2.3	4.3	.8	1.8	0	.25	.5	.3	0	0	0	2.8	13.0	25.5																											

Statistical Analysis of Performance

This group of tests was handled as for Group A, the mean bin months of protection being computed as tabulated below:

Series	Treatment	Bin-months of protection
-	No treatment--controls	24.3
16	1.67 p.p.m.	41.0

The difference between the treatments and the controls was tested for significance by the method of the analysis of variance. The analysis showed that the difference was significant. The variation ratio "F" of 7.8 was greater than the significant "F" value for these tests of 5.32 at the 5 percent level.

Insecticidal Residues

The residues of pyrethrins and piperonyl butoxide in the composited samples from the bins in the treated series are given in table 12. No analyses were made for pyrethrins until April 1956 pending the development of a more sensitive method. The first analysis for piperonyl butoxide made in November, based on an application rate of 16.7 p.p.m., showed a mean recovery of 13.4 p.p.m. or 80 percent. With the exception of the 2 low readings in April and August 1955, the mean recovery remained fairly constant at about 50 percent throughout the observation period. The pyrethrins recovery rates, with the exception of the April 1957 analysis, remained at about half the application rate.

Group H -- Tests with Wheat Begun in 1955 in Morris County, Kans.

A commercially available emulsion-type spray was used in these tests, on well-infested wheat at application rates above those previously tried, and with formulations containing pyrethrum combined with two different synergists, with one of the synergists alone and with pyrethrum alone. The wheat used in these tests was 1952 and 1953 crop wheat, and had been in storage at CCC bin sites at Dwight and White City, Morris County, Kans., since delivery from farm storage in May 1953 and 1954. The treatments were applied in September and October 1955 as the wheat was turned from one bin to another, by spraying the wheat as it ran into the hopper of the loading auger. The treatments were purposely delayed until a fairly high level of infestation had developed in order to determine whether the higher application rates of pyrethrins would control a vigorous self-contained infestation and prevent subsequent re-infestation. The wheat was sampled monthly in the standard pattern.

The formulations, application rates, and dosage rates were as follows:

Series 17. Five bins each were treated with a commercially available emulsion-type spray containing pyrethrins and piperonyl butoxide in 1 to 10 ratio, at an application rate of 5 gallons per 1,000 bushels, giving dosage rates of 1.5, 2.0, and 2.5 p.p.m. of pyrethrins, respectively.

Series 18. Five bins were treated with an experimental emulsion-type spray containing piperonyl butoxide alone at an application rate of 5 gallons per 1,000 bushels, giving a dosage rate of 25 p.p.m. of piperonyl butoxide.

Series 19. Five bins of wheat were treated with an experimental emulsion-type spray containing pyrethrins and piperonyl butoxide in 1 to 5 ratio, at a rate of 5 gallons per 1,000 bushels, giving a dosage of 1.36 p.p.m. of pyrethrins.

Table 12.--Residues found in samples of shelled corn from the treated bins in Group G, Missouri, 1954

Series, dosage rate, and bin number	Amounts of pyrethrins and piperonyl butoxide found in--												
	1954	1955				1956				1957			
	Nov.	Jan.	Apr.	Aug.	Oct.	Jan.	Apr.	July	Nov.	Jan.	Apr.	July	Oct.
Series 16. Pyrethrum-piperonyl butoxide emulsion-type spray													
Bin 167	*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.*	*P.p.m.*	*P.p.m.*
Pyrethrins	-	-	-	-	-	-	0.6	0.5	0.7	-	[1] T	0.5	0.5
Piperonyl butoxide	15.0	10.0	1.7	6.0	9.6	7.5	-	5.0	10.0	7.8	7.4	7.0	6.6
Bin 168													
Pyrethrins	-	-	-	-	-	-	.9	.9	.7	-	T	.4	.5
Piperonyl butoxide	16.0	9.0	0	2.0	8.8	8.3	-	9.0	10.0	8.4	7.8	7.5	6.6
Bin 169													
Pyrethrins	-	-	-	-	-	-	.6	1.0	.7	-	T	.4	.4
Piperonyl butoxide	14.0	13.0	3.5	2.0	8.0	6.4	-	10.0	9.5	8.2	7.8	6.5	6.6
Bin 170													
Pyrethrins	-	-	-	-	-	-	.6	.7	.6	-	T	.5	.4
Piperonyl butoxide	12.0	14.0	3.8	6.0	10.4	5.4	-	7.0	7.5	7.8	7.0	6.0	4.7
Bin 171													
Pyrethrins	-	-	-	-	-	-	.4	1.0	.7	-	T	.3	.5
Piperonyl butoxide	10.0	11.0	4.3	6.0	6.4	6.9	-	10.0	8.5	6.2	7.4	6.0	5.5
Mean													
Pyrethrins	-	-	-	-	-	-	.6	.8	.7	-	T	.4	.5
Piperonyl butoxide	13.4	11.4	2.7	4.4	8.6	6.9	-	8.2	9.1	7.7	7.5	6.5	6.0

[1] T = Trace, or less than 0.1 of 1 percent.

Series 20. Five bins of wheat each were treated with experimental emulsion-type sprays containing pyrethrins and MGK-264 in 1 to 5 and 1 to 10 ratios at an application rate of 5 gallons per 1,000 bushels, giving a dosage rate of 1.36 p.p.m. of pyrethrins in each case.

Series 21. Five bins of wheat were treated with an experimental emulsion-type spray containing pyrethrins alone, at an application rate of 5 gallons per 1,000 bushels, giving a dosage rate of pyrethrins of 1.36 p.p.m.

Fourteen bins which had been turned in the same manner as the treated bins were used as checks.

Insect Population Trends

The insect population trends in the treated and untreated control bins are given in table 13. In the untreated controls, the population had increased to the weevily level in 5 of the bins by February 1956; 2 more by March 1956; another by August 1956; another by October 1956; and one each in March and April 1957. The remaining 3 bins were continued through 1957 without developing excessive insect populations.

In Series 17, receiving 1.5, 2.0, and 2.5 p.p.m. of pyrethrins, the wheat remained virtually insect-free throughout the season of 1956. The 3 series were continued into 1957. In August 1957, 4 of the 5 bins receiving 1.5 p.p.m. of pyrethrins became weevily (table 13, bin numbers 178-182). None of the bins in the series receiving a dosage of 2.0 p.p.m. developed serious infestations during 1957 (bin numbers 183-187). Of those receiving 2.5 p.p.m., 1 became weevily in July 1957, and 2 developed populations of the weevily level in August 1957 (bin numbers 188-192).

One lot of wheat in Series 18, receiving a dosage of 25 p.p.m. of piperonyl butoxide only, became weevily in August 1956 and another in September 1956. The 3 remaining bins developed light infestations and were continued into the 1957 season. During 1957, 1 bin became weevily in August; the other 2 developed only light infestations (table 13, bin numbers 193-197).

Series 19, receiving 1.36 p.p.m. of pyrethrins, in 1 to 5 ratio with piperonyl butoxide, remained practically insect-free during the summer of 1956 and was carried into 1957. Light infestations developed during 1957 (bin numbers 198-202).

Series 20, receiving 1.36 p.p.m. of pyrethrins in 1 to 5 ratio with MGK-264, developed serious infestations shortly after treatment. The wheat in 4 bins became weevily by February 1956; the remaining bin carried through 1956 and became weevily in January 1957 (bins 203-207).

In Series 20, receiving pyrethrins in 1 to 10 ratio with MGK-264, the wheat in 1 bin became weevily in December 1955; 1 in August 1956; 1 in October 1956; and 1 in November 1956. The remaining bin became weevily in January 1957 (bins 208-212).

Series 21, receiving 1.36 p.p.m. of pyrethrins with no synergist, developed light infestations during the summer of 1956. With the exception of one bin of wheat which was fumigated because of infestation by dermestid beetles, the series was carried through 1957 with only light infestations developing (bins 213-217).

Table 13.--Living insects found per 1,000 grams of wheat in Group H tests, following application of synergized pyrethrum protective treatments in Kansas, 1955

Series, dosage rate, and bin number	1955		1956												1957											
	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Series 17. Pyrethrum-piperonyl butoxide emulsion-type spray																										
1.5 p.p.m. of pyrethrins	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.
Bin 178	0	-	-	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0.5	0	0	3.0	8.5				
Bin 179	0	-	-	0	0	0	0	0	0	0	0	0	0	0	.3	.3	0	.5	0	0	4.5	23.5				
Bin 180	0	-	-	0	0	0	0	0	0	0	0	.5	0	.3	0	.5	0	.3	0	.3	.8	38.5	-	-	-	-
Bin 181	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	.3				
Bin 182	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 p.p.m. of pyrethrins																										
Bin 183	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	3.0	0	.3	-	-
Bin 184	0	-	-	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	.3	0	0
Bin 185	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bin 186	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	-	-
Bin 187	0	-	-	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0
2.5 p.p.m. of pyrethrins																										
Bin 188	0	-	-	0	0	0	0	0	0	0	0	0	.5	0	0	0	0	0	0	.3	0	14.8				
Bin 189	0	-	-	.3	0	0	0	0	0	0	0	0	0	.3	0	0	.3	0	0	0	0	0	0	.5	-	-
Bin 190	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.3	0	0	0	0	0
Bin 191	0	-	-	0	0	0	.3	0	.8	.3	.3	0	0	0	0	.8	2.3	.8	0	.8	11.3					
Bin 192	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.8	5.8				
Series 18. Piperonyl butoxide emulsion-type spray																										
25 p.p.m. of piperonyl butoxide																										
Bin 193	0	-	-	0	0	0	0	0	0	.3	1.3	.5	1.3	.8	1.8	.8	2.3	.5	0	.5	.5	.8	1.5	.8	0	0
Bin 194	0	-	-	0	0	0	0	0	0	.5	.3	2.3	.8	.5	.5	.3	.3	0	1.0	0	2.3	14.0				
Bin 195	.3	-	-	0	0	0	0	0	0	.3	1.0	.5	2.0	2.5	1.3	1.0	0	0	.3	0	.3	3.0	1.8	.3	1.3	0
Bin 196	0	-	-	0	0	0	0	0	2.0	10.8																
Bin 197	.3	-	-	.5	0	0	0	0	0	0	6.0															
Series 19. Pyrethrum-piperonyl butoxide emulsion-type spray in 1 to 5 ratio																										
1.36 p.p.m. of pyrethrins																										
Bin 198	-	0	-	.3	0	0	0	0	0	0	.3	0	.3	.3	0	.3	0	0	.3	0	0	.3	1.0	1.5	1.0	.8
Bin 199	-	0	-	0	0	0	0	0	0	.5	.3	.3	0	0	0	0	.3	0	0	0	.5	1.3	4.5	-	-	-
Bin 200	-	0	-	0	0	0	0	0	0	0	0	0	1.3	.5	0	0	0	0	0	.3	1.3	.8	.8	1.8	-	-
Bin 201	-	0	-	0	0	0	0	0	0	.3	.5	0	0	0	0	0	0	0	0	.3	.5	.5	1.8	4.5	-	-
Bin 202	-	0	-	0	0	0	0	0	0	0	0	.3	0	0	0	0	0	0	0	0	0	.8	.5	.5	0	0
Series 20. Pyrethrum-MGK-264 emulsion-type spray																										
1.36 p.p.m. of pyrethrins (1 to 5 ratio)																										
Bin 203	-	1.8	-	16.5																						
Bin 204	-	0	-	0	0	0	0	0	0	.3	0	0	.3	.5	.5											
Bin 205	-	0	-	20.8																						
Bin 206	-	0	-	10.0																						
Bin 207	-	.8	-	25.5																						
1.36 p.p.m. of pyrethrins (1 to 10 ratio)																										
Bin 208	-	10.0																								
Bin 209	-	1.3	-	1.0	.3	.3	0	0	.8	4.8	2.5	4.8	6.8													
Bin 210	-	1.8	-	.8	.5	.5	.5	0	3.3	34.3																
Bin 211	-	.8	-	.3	0	.8	0	.3	0	.3	3.0	.3	2.3	.3	1.0											
Bin 212	-	1.8	-	0	.5	0	0	0	1.5	4.8	2.8	12.0														
Series 21. Pyrethrum emulsion-type spray																										
1.36 p.p.m. of pyrethrins																										
Bin 213	-	0	-	0	0	0	0	0	0	.5	1.5	3.3	1.8	.5	0	.3	.5	0	0	0	0	.5	.3	1.5	1.8	.8
Bin 214	-	0	-	.3	0	0	0	0	0	.5	1.3	.5	3.0	.5	0	0	1.3	.3	0	0	.3	0	.5	.3	.5	.3
Bin 215	-	.3	-	.3	.5	0	0	0	0	1.3	1.5	1.0	3.3	2.3	0	1.8	.8	.5	.3	.5	0	0	.8	2.0	1.0	2.0
Bin 216	-	2.0	-	.8	.3	0	0	0	.5	.8	2.5	2.8	2.8	.5	0	.3	0	0	.3	0	.8	.5	3.5	1.8	1.3	.8
Bin 217	-	.3	-	0	0	0	0	0	0	0	1.5	2.0	.5													
Check series																										
Bin 218	.8	-	-	2.0	5.0																					
Bin 219	13.0	-	-	7.8																						
Bin 220	.3	-	-	0	0	.8	0	.3	.5	1.5	2.3	3.5	3.3	0	2.0	1.5	1.3	9.0								
Bin 221	-	1.3	-	4.0	6.0																					
Bin 222	0	-	-	0	0	0	0	0	0	1.3	.3	.3	.3	1.3	.5	2.8	0	1.0	.8	0	.3	.3	3.5	1.0	2.0	2.3
Bin 223	0	-	-	0	0	0	0	0	0	.5	0	.5	.8	1.3	1.5	.3	0	2.5	0	0	0	1.0	.8	1.5	3.3	.5
Bin 224	-	0	-	0	0	0	.3	0	0	1.3	1.8	3.3														
Bin 225	-	4.5	-	8.3																						
Bin 226	-	.8	-	1.8	.8	1.0	1.0	0	0	.3	.3	.3	.8	.8	.5	0	.5	.3	0	0	0	0	.5	0	.8	.3
Bin 227	-	1.3	-	5.0																						
Bin 228	-	1.3	-	9.0																						
Bin 229	-	1.0	-	1.5	3.3	1.0	.8	0	0	.5	2.3	2.5	.5	1.8	0	1.3	8.8									
Bin 230	-	0	-	0	0	0	0	0	1.8	10.0																
Bin 231	-	3.5	-	6.8																						

Statistical Analysis of Performance

This group of tests was handled as for Group A, the mean bin months of protection being computed as tabulated below:

Series	Treatment	Bin-months of protection
-	No treatment--controls	9.8
17	1.5 p.p.m. (pyrethrins-piperonyl butoxide)	23.0
	2.0 p.p.m. (pyrethrins-piperonyl butoxide)	25.0
	2.5 p.p.m. (pyrethrins-piperonyl butoxide)	22.4
18	25 p.p.m. piperonyl butoxide only	17.6
19	1.36 p.p.m. (pyrethrins-piperonyl butoxide in 1 to 5 ratio)	25.0
20	1.36 p.p.m. (pyrethrins-MGK-264 in 1 to 5 ratio)	4.4
	1.36 p.p.m. (pyrethrins-MGK-264 in 1 to 10 ratio)	8.6
21	1.36 p.p.m. (pyrethrins alone)	25.0

The differences between the treatments and the controls, and between treatments, were tested for significance by the method of the analysis of variance. This analysis showed that there were significant differences. The least significant differences between means were then computed. On the basis of this calculation, there were found to be significant differences between:

The untreated controls and all three parts of Series 17 (pyrethrins 1.5, 2.0, and 2.5 p.p.m. and piperonyl butoxide in 1 to 10 ratio)

The untreated controls and Series 18 (piperonyl butoxide alone)

The untreated controls and Series 19 (pyrethrins and piperonyl butoxide in 1 to 5 ratio)

The untreated controls and Series 21 (pyrethrins alone)

Series 17 all parts (pyrethrins 1.5, 2.0, and 2.5 and piperonyl butoxide in 1 to 10 ratio) and Series 20 all parts (pyrethrins 1.36 p.p.m. and MGK-264 in 1 to 5 and 1 to 10 ratios)

Series 18 (piperonyl butoxide 25 p.p.m.) and all parts of Series 20 (pyrethrins 1.36 p.p.m. and MGK-264 in 1 to 5 and 1 to 10 ratios)

Series 19 (pyrethrins 1.36 p.p.m. and piperonyl butoxide in 1 to 5 ratio) and all parts of Series 20 (pyrethrins 1.36 p.p.m. and MGK-264 in 1 to 5 and 1 to 10 ratios).

These analyses showed that the degree of protection in wheat treated with dosages of pyrethrins in the range of 1.36 to 2.50 p.p.m. synergized with piperonyl butoxide was significantly longer than that in the untreated controls. Piperonyl butoxide at 25 p.p.m. gave significantly longer protection than the untreated controls. Pyrethrins alone also produced a significantly longer protection than the untreated controls.

Comparing treatments, there were no significant differences between the series treated with the various pyrethrins-piperonyl butoxide formulations. There were, however, significant differences between the pyrethrins-piperonyl butoxide and the pyrethrins-MGK-264 formulations. The reduced dosage of MGK-264 gave the poorest results of any of the formulations tested in this series of trials. This poor performance of MGK-264 in these tests was due, partly at least, to an infestation of rice weevils in this series of bins, whereas in the other series tested on these sites, no weevil infestation was observed. The weevily level of population with weevils is 2 per 1,000 grams while

that for bran beetle infestation is 5 per 1,000 grams of wheat. The performance in corn (See Group B, Series 6 and 7) was much better. The protection given by the pyrethrins-MGK-264 (1 to 10) formulation was significantly greater than that given by the reduced dosage (1 to 5). It is of interest to note that there was no significant difference between the performance of pyrethrins alone and that of the synergized formulations.

Insecticidal Residues

The residues of pyrethrins and piperonyl butoxide found in the composited samples from the bins in each treated series are given in table 14. These analyses exhibit somewhat more uniformity than was the case in some of the earlier work. The percentage of recovery after aging for 2, 12, and 24 months is tabulated below:

Series	Mean of bin numbers	Treatment	Percent recovery after aging		
			2 Months	12 Months	24 Months
17	178-182	1.5 p.p.m. of pyrethrins	40	20	40
	183-187	2.0 p.p.m. of pyrethrins	59	30	25
	188-192	2.5 p.p.m. of pyrethrins	54	28	28
18	193-197	25 p.p.m. of piperonyl butoxide	83	61	58
19	198-202	1.36 p.p.m. of pyrethrins	46	30	Trace
20	203-207	1.36 p.p.m. of pyrethrins with MGK-264, 1 to 5 ratio	40	30	-
	208-212	1.36 p.p.m. of pyrethrins with MGK-264, 1 to 10 ratio	20	22	-
21	213-217	1.36 p.p.m. of pyrethrins	26	22	15

Two months after application, an average of about 50 percent of the application rate of pyrethrins was recovered. Twelve months after application, this was reduced to about 25 percent, and remained at about this level through 1957. The recovery of piperonyl butoxide (Series 18) remained high.

Bioassay Tests

The results of the bioassay tests are given in tables 15, 16, and 17. From these data it is evident that the highest potency of the pyrethrins was recorded 1 month after application to the grain, and declined rapidly during the first 3 months after treatment. From that time the mortalities in the bioassay tests tended to level off and remained at a low level for a long time, up to 30 months in 2 cases where the tests were continued for that length of time. There was also great variation in the mortality in successive samples from the same source.

CHANGES IN MOISTURE CONTENT

The wheat used in these tests was of about average moisture content, ranging from 10.0 to 12.3 percent in the different lots. The moisture determinations of the samples drawn at monthly intervals after treatment showed that, while there was a constant transfer of moisture within the grain mass, the overall moisture content remained virtually constant throughout the observation period. Of 20 lots observed, the moisture content increased in 13 lots an average of 0.5 percent; decreased in 5 lots an average of 0.2 percent; and was unchanged in 2 lots. Within the moisture range of this wheat, there was no apparent effect on the performance of the protective treatments.

Table 14.--Residues found in samples of wheat from the treated bins in Group H, Kansas, 1955-1957

Series, dosage rates, and bin numbers	Amounts of pyrethrins and piperonyl butoxide found in--							
	1955	1956			1957			
	Dec.	Feb.	July	Oct.	Jan.	Apr.	July	Oct.
Series 17. Pyrethrum-piperonyl butoxide emulsion-type spray								
1.5 p.p.m. of pyrethrins								
Bin 178	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Pyrethrins	0.4	0.3	0.9	0.3	0.7	0.4	0.7	-
Piperonyl butoxide	3.3	-	-	8.0	9.2	4.3	6.9	-
Bin 179								
Pyrethrins	.5	.3	.9	.3	T	.6	.7	-
Piperonyl butoxide	-	-	-	8.0	8.4	5.3	6.9	-
Bin 180								
Pyrethrins	.2	.4	.3	.3	T	.3	.7	-
Piperonyl butoxide	2.6	-	-	7.5	5.2	6.9	4.6	-
Bin 181								
Pyrethrins	.6	.5	.1	.2	1.3	.8	.6	-
Piperonyl butoxide	3.0	-	-	8.0	10.0	7.2	9.7	-
Bin 182								
Pyrethrins	1.2	.8	.6	.3	1.2	.6	1.4	.6
Piperonyl butoxide	4.0	-	-	12.0	9.8	7.2	11.4	9.4
Mean								
Pyrethrins	.6	.5	.6	.3	.8	.5	.8	.6
Piperonyl butoxide	3.2	-	-	8.7	8.5	6.2	7.9	9.4
2.0 p.p.m. of pyrethrins								
Bin 183								
Pyrethrins	.8	.8	.4	.6	1.4	.7	1.1	.6
Piperonyl butoxide	-	-	-	11.0	11.0	7.2	9.1	9.8
Bin 184								
Pyrethrins	1.4	.3	.4	.3	1.1	.6	.8	.6
Piperonyl butoxide	-	-	-	8.0	9.4	7.7	11.4	9.4
Bin 185								
Pyrethrins	1.2	.5	.6	.6	1.8	1.1	1.0	.5
Piperonyl butoxide	-	-	-	12.0	15.2	10.2	10.3	10.3
Bin 186								
Pyrethrins	1.2	1.1	.6	.8	1.0	.9	.7	.7
Piperonyl butoxide	-	-	-	12.5	12.6	8.9	10.3	11.2
Bin 187								
Pyrethrins	1.4	.6	.7	.8	.6	.7	1.1	.3
Piperonyl butoxide	-	-	-	10.0	10.4	6.8	9.7	9.4
Mean								
Pyrethrins	1.2	.7	.5	.6	1.2	.8	.9	.5
Piperonyl butoxide	-	-	-	10.7	11.7	8.2	10.2	10.0
2.5 p.p.m. of pyrethins								
Bin 188								
Pyrethrins	2.0	.6	.6	.6	1.1	1.1	.7	-
Piperonyl butoxide	-	-	-	9.5	10.0	8.6	9.1	-
Bin 189								
Pyrethrins	1.8	.5	.9	.8	.4	1.0	.7	.5
Piperonyl butoxide	-	-	-	10.5	10.4	9.7	8.6	9.4

Continued

Table 14.--Residues found in samples of wheat from the treated bins in Group H, Kansas, 1955-1957--Continued

Series, dosage rates, and bin numbers	Amounts of pyrethrins and piperonyl butoxide found in--							
	1955	1956			1957			
	Dec.	Feb.	July	Oct.	Jan.	Apr.	July	Oct.
Series 17. Pyrethrum-piperonyl butoxide emulsion-type spray--Continued								
Bin 190	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Pyrethrins	1.3	0.4	1.0	0.8	1.4	1.0	0.8	0.9
Piperonyl butoxide	6.2	-	-	13.0	17.0	10.6	11.7	14.5
Bin 191								
Pyrethrins	1.0	.7	1.0	.6	.6	.9	.8	-
Piperonyl butoxide	5.9	-	-	10.5	6.6	7.7	8.6	-
Bin 192								
Pyrethrins	.7	.6	1.3	.5	T	.7	.7	-
Piperonyl butoxide	-	-	-	12.0	10.4	7.8	9.7	-
Mean								
Pyrethrins	1.4	.6	1.0	.7	.9	.9	.7	.7
Piperonyl butoxide	6.0	-	-	11.1	10.9	8.9	9.5	12.0
Series 18. Piperonyl butoxide emulsion-type spray 25 p.p.m. piperonyl butoxide								
Bin 193								
Piperonyl butoxide	23.5	17.3	13.8	16.0	20.2	4.1	25.1	16.4
Bin 194								
Piperonyl butoxide	29.5	17.3	14.5	15.0	18.8	13.8	23.6	-
Bin 195								
Piperonyl butoxide	16.0	14.2	11.0	12.8	15.6	10.6	17.1	12.6
Bin 196								
Piperonyl butoxide	16.5	13.0	11.0	-	-	-	-	-
Bin 197								
Piperonyl butoxide	18.0	13.8	13.8	13.2	-	-	-	-
Mean								
Piperonyl butoxide	20.7	15.1	14.8	15.3	18.2	9.5	21.9	14.5
Series 19. Pyrethrum-piperonyl butoxide emulsion-type spray in 1 to 5 ratio 1.36 p.p.m. of pyrethrins								
Bin 198								
Pyrethrins	.4	.5	.8	.4	.4	.6	T	-
Piperonyl butoxide	-	-	-	1.7	3.8	3.4	3.3	3.0
Bin 199								
Pyrethrins	.8	.4	.8	.4	.5	.4	T	-
Piperonyl butoxide	3.6	-	-	2.2	5.2	4.3	3.9	3.0
Bin 200								
Pyrethrins	.6	.3	.6	.4	.5	.7	T	-
Piperonyl butoxide	2.7	-	-	2.2	5.2	3.7	3.9	3.3
Bin 201								
Pyrethrins	.8	.5	.8	.5	.4	.5	T	-
Piperonyl butoxide	3.2	-	-	2.3	4.6	3.9	4.5	3.5

Continued

Table 14.--Residues found in samples of wheat from the treated bins in Group H, Kansas, 1955-1957--Continued

Series, dosage rates, and bin numbers	Amounts of pyrethrins and piperonyl butoxide found in--							
	1955	1956			1957			
	Dec.	Feb.	July	Oct.	Jan.	Apr.	July	Oct.
Series 19. Pyrethrum-piperonyl butoxide emulsion-type spray in 1 to 5 ratio--Continued								
Bin 202	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Pyrethrins	0.5	0.3	0.6	0.5	0.4	0.4	T	-
Piperonyl butoxide	2.5	-	-	2.5	4.6	3.1	3.9	3.5
Mean								
Pyrethrins	.6	.4	.7	.4	.4	.5	T	-
Piperonyl butoxide	3.0	-	-	2.2	4.7	3.7	3.9	3.3
Series 20. Pyrethrum-MGK-264 emulsion-type spray 1.36 p.p.m. of pyrethrins (1 to 5 ratio)								
Bin 203								
Pyrethrins	.7	.7	-	-	-	-	-	-
Bin 204								
Pyrethrins	.5	.3	.2	.4	.6	-	-	-
Bin 205								
Pyrethrins	.3	.3	-	-	-	-	-	-
Bin 206								
Pyrethrins	.7	.7	-	-	-	-	-	-
Bin 207								
Pyrethrins	.4	.4	-	-	-	-	-	-
Mean								
Pyrethrins	.5	.5	.2	.4	.6	-	-	-
Series 20. Pyrethrum-MGK-264 emulsion-type spray 1.36 p.p.m. of pyrethrins (1 to 10 ratio)								
Bin 208								
Pyrethrins	.3	-	-	-	-	-	-	-
Bin 209								
Pyrethrins	.3	.3	.5	.3	-	-	-	-
Bin 210								
Pyrethrins	.2	.3	.8	-	-	-	-	-
Bin 211								
Pyrethrins	.2	.3	.4	.3	.5	-	-	-
Bin 212								
Pyrethrins	.2	.4	.6	.3	-	-	-	-
Mean								
Pyrethrins	.2	.3	.6	.3	.5	-	-	-

Continued

Table 14.--Residues found in samples of wheat from the treated bins in Group H, Kansas, 1955-1957--Continued

Series, dosage rates, and bin numbers	Amounts of pyrethrins and piperonyl butoxide found in--							
	1955	1956			1957			
	Dec.	Feb.	July	Oct.	Jan.	Apr.	July	Oct.
Series 21. Pyrethrum-emulsion-type spray								
1.36 p.p.m. of pyrethrins								
Bin 213	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Pyrethrins	0.4	0.4	0.3	0.3	0.4	0.7	0.6	0.3
Bin 214								
Pyrethrins	.5	T	.2	.4	.4	.8	.7	.2
Bin 215								
Pyrethrins	.2	T	.2	.2	.4	.6	.6	.2
Bin 216								
Pyrethrins	.3	.2	.3	.3	.4	.4	.6	.3
Bin 217								
Pyrethrins	.4	.4	.5	.3	-	-	-	-
Mean								
Pyrethrins	.4	.2	.3	.3	.4	.6	.6	.2

The corn used in the tests was dry enough to store, with the exception of that in the Illinois tests (See Group D Tests). The average moisture content of the different lots ranged from 10.3 to 13.1 percent. The usual continual transfer of moisture was noted, in the surface corn during the winter months, followed by a redistribution during the summer months. The overall moisture content of the various lots of corn remained nearly constant during the storage period. Of 22 lots observed, the moisture content increased in 12 lots an average of 0.6 percent; decreased in 9 lots an average of 0.6 percent; and was unchanged in one lot. Within the moisture range of the corn used in these tests, there was no apparent effect on the performance of the protective treatments.

CHANGES IN THE COMMERCIAL GRADE

The commercial grade of the bins of wheat, taken at the beginning of the study and at quarterly intervals thereafter, showed that there was no down-grading because of the treatment. Further, of 51 bins of wheat observed, no change in grade occurred for any cause. Inasmuch as observations in many bins are being continued, the final grades have not been determined for all of the tests.

The commercial grade of the bins of corn in one series was down-graded because of the treatment. In Group A, Series 1, the talc carrier imparted a gritty feel to the corn and it was ruled DLQ (distinctly low quality) for that reason.

However, the corn in 73 of 94 bins under observation was down-graded from one to five grades because of increase in total damage during the storage period. This was due primarily to moisture accumulation in the surface grain during the winter months, resulting in varying amounts of spoilage, chiefly in the surface corn in the center of the bin.

Table 15.--Mortality of adult rice weevils in bioassay tests with samples taken at intervals from stored wheat treated with pyrethrum protective formulations

Series, dosage rate, and exposure period	Percentage mortality of test insects in samples taken in--					
	1953		1954			
	July	Oct.	Jan.	April	July	Oct.
Series 8. Pyrethrum-piperonyl butoxide dust, at a rate of 1.08 p.p.m. of pyrethrins	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1 week's exposure.....	50	9	2	1	1	8
3 weeks' exposure.....	95	45	17	2	10	15
Series 9. Pyrethrum-piperonyl butoxide solution-type spray 1.08 p.p.m. of pyrethrins						
1 week's exposure.....	34	2	1	1	1	9
3 weeks' exposure.....	94	3	16	6	0	4
1.62 p.p.m. of pyrethrins						
1 week's exposure.....	34	15	9	2	2	6
3 weeks' exposure.....	77	20	13	4	2	10
2.16 p.p.m. of pyrethrins						
1 week's exposure.....	79	13	17	4	6	11
3 weeks' exposure.....	91	44	33	20	16	28
Series 10. Pyrethrum-piperonyl butoxide emulsion-type spray 1.36 p.p.m. of pyrethrins (10-gal. rate)						
1 week's exposure.....	12	10	4	0	4	0
3 weeks' exposure.....	90	30	14	0	4	0
2.05 p.p.m. of pyrethrins						
1 week's exposure.....	60	0	0	0	2	6
3 weeks' exposure.....	100	40	4	4	2	6
1.36 p.p.m. of pyrethrins (5-gal. rate)						
1 week's exposure.....	43	7	4	0	3	8
3 weeks' exposure.....	96	28	47	18	13	11
Check series						
1 week's exposure.....	40	7	9	2	1	0
3 weeks' exposure.....	77	21	13	11	1	2

COMPARATIVE ABUNDANCE OF SPECIES OF INSECTS

The monthly samples drawn from the bins were examined in the laboratory and the number and species of stored-grain insects were recorded. The comparative abundance of the different species is given in tables 18 and 19, expressed as percentages of the total number of insects found during 3-month periods.

Table 16.--Mortality of adult rice weevils and confused flour beetles in bioassay tests with samples taken at intervals from stored shelled corn treated with pyrethrum protective formulations

Series, dosage rate, exposure period, and test insect	Mortality in bioassay tests following sampling in--										
	1952	1953					1954				1955
	Oct.	Jan.	April	June	Aug.	Dec.	March	June	Sept.	Dec.	March
Series 3. Pyrethrum-sulfoxide dust at a rate of											
1.43 p.p.m. of pyrethrins											
1 week's exposure	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Flour beetles.....	8	-	3	15	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	38	100	72	21	8	36	4
3 weeks' exposure											
Flour beetles.....	38	51	18	16	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	42	100	100	8	12	48	16
Series 2. Pyrethrum-piperonyl butoxide dust											
1.07 p.p.m. of pyrethrins											
1 week's exposure											
Flour beetles.....	8	-	6	2	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	12	-	-	-	-	-	-
3 weeks' exposure											
Flour beetles.....	12	35	31	15	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	8	-	-	-	-	-	-
1.43 p.p.m. of pyrethrins											
1 week's exposure											
Flour beetles.....	8	-	1	18	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	12	80	8	8	32	12	0
3 weeks' exposure											
Flour beetles.....	52	41	32	36	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	80	100	100	8	32	28	0

Continued

Table 16.--Mortality of adult rice weevils and confused flour beetles in bioassay tests with samples taken at intervals from stored shelled corn treated with pyrethrum protective formulations--Continued

Series, dosage rate, exposure period, and test insect	Mortality in bioassay tests following sampling in--										
	1952	1953					1954				1955
	Oct.	Jan.	April	June	Aug.	Dec.	March	June	Sept.	Dec.	March
Series 1. Pyrethrum-piperonyl butoxide dust, at a rate of 0.89 p.p.m.											
1 week's exposure	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Flour beetles.....	36	-	0	6	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	73	-	-	-	-	-	-
3 weeks' exposure											
Flour beetles.....	65	23	57	26	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	40	-	-	-	-	-	-
Series 5. Pyrethrum-piperonyl butoxide spray at a rate of 1.23 p.p.m.											
1 week's exposure											
Flour beetles.....	23	-	3	8	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	47	89	19	6	5	8	7
3 weeks' exposure											
Flour beetles.....	43	18	57	16	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	31	100	83	4	5	60	33
Series 4. Pyrethrum-piperonyl butoxide spray at a rate of 1.04 p.p.m. of pyrethrins											
1 week's exposure											
Flour beetles.....	2	-	-	11	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	31	-	-	-	-	-	-
3 weeks' exposure											
Flour beetles.....	40	22	42	19	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	11	-	-	-	-	-	-

Continued

Table 16.--Mortality of adult rice weevils and confused flour beetles in bioassay tests with samples taken at intervals from stored shelled corn treated with pyrethrum protective formulations--Continued

Series, dosage rate, exposure period, and test insect	Mortality in bioassay tests following sampling in--										
	1952	1953					1954				1955
	Oct.	Jan.	April	June	Aug.	Dec.	March	June	Sept.	Dec.	March
Check series											
1 week's exposure	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Flour beetles.....	1	-	1	8	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	5	-	-	-	-	-	-
3 weeks' exposure											
Flour beetles.....	-	11	17	6	-	-	-	-	-	-	-
Rice weevils.....	-	-	-	-	8	-	-	-	-	-	-

Table 17.--Mortality of adult rice weevils in bioassay tests with samples taken at intervals from stored shelled corn treated with pyrethrum protective formulations

Series, dosage rate, and exposure period	Mortality in bioassay tests following sampling in--					
	1953		1954			
	July	Oct.	Jan.	April	July	Oct.
Series 11. Pyrethrum-piperonyl butoxide solution-type spray						
1.16 p.p.m. of pyrethrins	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1 week's exposure.....	80	20	38	10	17	3
3 weeks' exposure.....	92	42	67	30	23	50
2.32 p.p.m. of pyrethrins						
1 week's exposure.....	95	41	72	20	4	21
3 weeks' exposure.....	100	56	96	46	17	55
Series 6. Pyrethrum-MGK-264 solution-type spray						
1.32 p.p.m. of pyrethrins						
1 week's exposure.....	-	3	0	1	0	10
3 weeks' exposure.....	-	7	3	1	8	25
Series 7. Pyrethrum-MGK-264 water-emulsion-type spray						
1.32 p.p.m. of pyrethrins						
1 week's exposure.....	-	1	1	3	0	11
3 weeks' exposure.....	-	6	7	5	8	35
Series 12. Pyrethrum-piperonyl butoxide dust at a rate of						
1.07 p.p.m. of pyrethrins						
1 week's exposure.....	96	34	81	50	2	3
3 weeks' exposure.....	100	79	91	96	8	26
2.14 p.p.m. of pyrethrins						
1 week's exposure.....	96	87	99	72	50	70
3 weeks' exposure.....	100	100	100	99	70	96
Check series						
1 week's exposure.....	0	2	0	0	0	-
3 weeks' exposure.....	4	9	0	6	5	-

A total of 13 species of stored-grain insects was found in the wheat (table 18).

In the wheat treated with dusts and sprays, dermestids (Trogoderma spp.) were the most abundant species of insects; and in the untreated controls, the flat grain beetle was most numerous and the dermestids ranked third in number.

In the corn, a total of 19 species was recorded. In the corn treated with dusts, the red flour beetle was the most abundant species, with the flat grain beetle ranking second and the rice weevil third. In the series treated with sprays, the saw-toothed grain beetle was most abundant, with the red flour beetle ranking second and the flat grain beetle third in number. In the untreated controls, the flat grain beetle was first in abundance, with the red flour beetle second and the saw-toothed grain beetle third (table 19).

Table 18.--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						
	June-July	Aug.-Oct.	Nov.-Jan.	Feb.-Apr.	May-July	Aug.-Oct.	Nov.-Jan.	Feb.-Apr.	May-July	Aug.-Oct.	Nov.		
Treated series--dusts	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*
Lesser grain borer	0	10.6	20.0	0	5.3	2.2	16.0	0	0	0	0	685	6.0
Dermestidae[2]	0	2.6	20.0	0	94.7	97.3	83.5	99.4	100.0	100.0	100.0	10,693	93.2
Red flour beetle	87.5	81.6	40.0	100.0	0	.4	.2	.3	0	0	0	79	.7
Flat grain beetle[3]	0	0	0	0	0	0	.3	0	0	0	0	11	.1
Cadelle	0	2.6	0	0	0	.1	0	0	0	0	0	2	T
Hairy fungus beetle	6.3	0	0	0	0	0	0	0	0	0	0	1	T
Indian-meal moth	0	2.6	20.0	0	0	0	0	0	0	0	0	3	T
Long-headed flour beetle	6.3	0	0	0	0	0	0	.3	0	0	0	2	T
Total number of insects observed[4]	(16)	(38)	(10)	(14)	(19)	(1,782)	(3,973)	(330)	(767)	(4,242)	(285)	(11,476)	
Treated series--sprays													
Rice weevil	7.5	3.6	2.7	0	0	0	0	0	.2	0	0	36	.7
Granary weevil	2.5	20.2	7.4	0	0	0	0	0	0	0	0	118	2.2
Lesser grain borer	0	.7	.3	39.1	1.3	10.3	16.4	0	0	0	0	146	2.7
Dermestidae[2]	0	6.3	2.8	30.4	97.4	78.1	72.7	98.8	99.5	97.3	16.5	3,912	72.8
Flat grain beetle[3]	47.5	25.8	47.0	21.7	0	1.5	4.2	0	.3	2.4	79.6	622	11.6
Red flour beetle	37.5	20.9	39.0	4.4	0	.8	1.1	.3	0	.1	0	386	7.2
Saw-toothed grain beetle	5.0	15.6	.7	4.4	1.3	7.6	1.8	.9	0	.2	3.9	106	2.0
Indian-meal moth	0	.7	.1	0	0	.8	3.7	0	0	0	0	27	.5
Cadelle	0	5.0	0	0	0	.3	.2	0	0	0	0	17	.3
Foreign grain beetle	0	1.3	0	0	0	.3	0	0	0	0	0	5	.1
Angoumois grain moth	0	0	0	0	0	.3	0	0	0	0	0	1	T
Total number of insects observed[4]	(40)	(302)	(754)	(23)	(79)	(379)	(568)	(324)	(674)	(2,130)	(103)	(5,376)	
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 1460 (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 19.--Comparative abundance of the species of stored grain insects found in samples of shelled corn 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.		
Treated series--dusts	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*
Rice weevil	0	0	1.0	14.1	37.5	15.6	6.1	12.2	55.6	7.4	8.3	188	8.1
Granary weevil	6.3	0	0	0	0	0	.5	0	0	0	0	3	.1
Red flour beetle	9.4	11.2	54.2	78.3	26.8	53.5	79.3	26.8	16.7	69.6	64.6	1,152	49.5
Foreign grain beetle	3.1	40.5	25.3	0	0	0	0	0	0	0	0	312	13.4
Hairy fungus beetle	31.3	21.9	10.4	0	1.8	0	0	0	0	.9	18.8	174	7.5
Flat grain beetle[2]	21.9	18.8	2.0	4.5	10.7	5.2	2.0	14.6	0	4.8	0	168	7.2
Saw-toothed grain beetle	3.1	0	.8	0	5.4	18.1	2.0	2.4	11.1	7.8	0	133	5.7
Dermestidae[3]	0	0	.6	2.0	5.4	3.8	8.6	36.6	5.6	3.9	6.3	76	3.2
Indian-meal moth	21.9	2.0	3.2	1.0	1.8	3.6	0	0	0	2.6	0	61	2.6
Angoumois grain moth	0	5.5	2.2	0	7.1	.2	1.0	0	0	3.0	2.1	51	2.2
Cadelle	0	0	0	0	3.6	0	.5	7.3	11.1	0	0	8	.3
Red-horned grain beetle	3.1	.2	.2	0	0	0	0	0	0	0	0	3	.1
Total number of insects observed[4]	(32)	(457)	(498)	(198)	(56)	(553)	(198)	(41)	(18)	(230)	(48)	(2,329)	
Treated series--sprays													
Rice weevil	0	7.5	.9	1.7	0	10.3	1.7	1.8	2.4	3.2	2.8	186	4.0
Granary weevil	1.4	0	0	0	0	.2	0	0	0	.1	0	3	T
Lesser grain borer	0	0	0	0	0	2.4	0	0	0	0	0	13	.3
Red flour beetle	2.8	12.5	47.7	85.3	0	17.8	35.6	75.2	.3	10.7	45.5	1,248	26.5
Saw-toothed grain beetle	37.5	4.7	.8	0	0	22.4	26.1	1.4	42.7	64.9	13.9	1,209	25.7
Flat grain beetle[2]	6.9	35.5	10.4	4.3	0	20.6	20.7	19.1	17.0	12.5	17.6	842	17.9
Indian-meal moth	44.4	6.2	9.8	8.6	85.4	18.7	13.6	0	33.7	1.7	8.6	488	10.4
Foreign grain beetle	1.4	19.9	23.0	0	0	.6	0	0	2.1	1.3	0	387	8.2
Hairy fungus beetle	2.8	10.0	6.1	0	2.4	0	0	0	0	.3	0	140	3.0
Dermestidae[3]	0	.1	.2	0	0	1.0	1.4	.7	.7	4.1	4.3	73	1.6
Angoumois grain moth	0	2.9	.5	0	12.2	4.6	.7	0	.3	.1	0	61	1.3
Larger black flour beetle	0	.1	.4	0	0	.4	0	0	0	.9	7.5	31	.7
Cadelle	2.8	.4	.1	0	0	1.0	0	.7	0	0	0	13	.3
Yellow meal worm	0	0	0	0	0	0	.3	.7	.7	.1	0	6	.1
Long-headed flour beetle	0	0	.2	0	0	.4	0	.4	0	0	0	5	.1
Two-banded fungus beetle	0	0	.2	0	0	0	0	0	0	0	0	1	T
Total number of insects observed[4]	(72)	(788)	(884)	(116)	(41)	(545)	(295)	(278)	(288)	(1,212)	(187)	(4,706)	

See footnotes at end of table.

Table 19.--Comparative abundance of the species of stored grain insects found in samples of shelled corn taken from the test bins, 1953-56--Continued

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.		
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[2]	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[3]	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[4]	(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. Farmer's Bulletin 1260 (rev.) Aug. 1955. [2] Probably a complex of 3 species: Laemophloeus pusillus (Schönh.), L. ferrugineus (Steph.), and L. turcicus Grouv. [3] Trogoderma spp. [4] Numbers in parentheses represent the total number of insects found during each period and are not percentages.

FINDINGS

Although the work with pyrethrum protective treatments is still in progress, the following points were established by the tests:

1. Pyrethrum dust and spray formulations protected stored wheat and shelled corn for long periods of storage.

2. Applications of 1.5, 2.0, and 2.5 p.p.m. of pyrethrins synergized with piperonyl butoxide in the ratio of 1 to 10 controlled existing infestations and were highly effective in wheat during 2 summer seasons following application. Lower rates of application gave protection during the first summer season but were depleted during the second season.

3. When used at reduced dosages (ratio 1 to 5) the effectiveness of one of the synergists was greatly reduced, and that of the other was not greatly affected.

4. In tests with shelled corn, dosages ranging from 0.89 to 2.32 p.p.m. of synergized pyrethrins were highly effective for 1, 2, or 3 summer seasons following application, depending on the formulation and dosage.

5. The residues of pyrethrins and piperonyl butoxide were generally much less than the application rate, usually about 50 percent of the application rate.

6. The depletion of the residues was usually rapid during the first month after treatment, and then tended to level off.

7. The bioassays produced erratic results, but in general, the mortalities were far below the expected as compared with the degree of protection observed in the tests. This would indicate a high degree of repellency in the treated grain after the residues were degraded below the toxic level.

8. A moisture content of 12.3 percent or less in wheat, or of 13.1 percent in shelled corn, did not affect the performance of the protective treatments.

9. The commercial grade of the wheat was not affected by any of the protective formulations. The commercial grade of the shelled corn was adversely affected by the dust formulated on a talc carrier, which imparted a gritty feel to the corn. None of the other formulations affected the grade.

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