CONTROLLING
ROOT-FEEDING INSECTS OF CORN

A report of a 10-year study

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CONTROLLING ROOT-FEEDING INSECTS OF CORN

THE UNDERGROUND PORTIONS OF THE CORN PLANT are subject to attack by several insects which use the seed and roots as their principal food. The plant may be exposed to insect attack from planting time to maturity.

Certain insects attack only the seed. These are the seed-corn maggot, *Hylemya cilicrura* (Rondani), and the two seed-corn beetles, *Agonoderus lecontei* Chadoir and *Clivina impressifrons* Leconte. Insects attacking only the root are white grubs, *Phyllophaga* spp. and *Cyclocephala* spp.; northern corn rootworm, *Diabrotica longicornis* (Say); southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber; and corn-root aphid, *Anuraphis maidiradicis* (Forbes). The corn-root aphid is usually accompanied in a symbiotic relationship by the cornfield ant, *Lasius alienus* (Forster). Wireworms, *Elateridae,* may attack either the seed, roots, or base of the stalk, and the black cutworm, *Agrotis ipsilon* (Hufnagel), attacks the stem either underground or at the soil surface. The grape colaspis, *Maecolaspis flavida* (Say), feeds on tiny rootlets or the underground stem of seedling plants.

The group of economically important insects attacking the underground portions of the corn plant in Illinois are particularly annoying pests because their feeding on the plant is hidden until the damage has been done, and it is usually too late to apply control measures when the damage is discovered.

These pests have been an agricultural problem in Illinois from the time that corn was first grown extensively in the state. Entomologists have constantly sought means of preventing this damage since the middle of the 19th century. It is especially difficult to study these insects since their habitat must be destroyed to determine their presence or abundance on the plant. Preventive measures are the only feasible method of attack.

Early attempts to control the insects through cultural practices frequently produced satisfactory results, but a procedure which controlled one insect often had no effect on some others. The procedures also at times did not agree with accepted agronomic practices and interfered with farm work programs. During the 1940's certain insecticides became available which were thought to hold promise for use in solving this problem.

Review of Literature and History of Investigations

Attempts to control root-feeding insects by the use of soil treatments have been reported on numerous occasions during the past century. In 1917 Hinds,[10]* referring to soil treatments for control of the grape phylloxera in France, reported that carbon bisulfide was being used to control this pest in 1863. In 1907 Smith[12] recommended using this insecticide around the roots of plants to control cabbage maggot, and in 1909 Newell[11] recommended it as a soil treatment to control the Argentine ant. In 1926 Davis[3] recommended the use of carbon bisulfide in the soil of lawns for white grub control.

During the 1907 to 1926 period many other materials were tested, but none was consistently recommended. In other tests, arsenic compounds were mixed very successfully in soil for white grub control. The high cost of both arsenic compounds and carbon bisulfide, plus the danger of handling the latter, limited and eventually ended their use as soil treatments.

The use of repellents applied to seed was investigated in Illinois as early as 1905 and 1906.[5] At that time 38 or more materials were tested, of which the following are typical of groups: kerosene, mustard, oil of lemon, flowers of sulfur, copper sulfate, and Scalecide (an oil emulsion). By 1915, however, farmers were warned[6] not to use these materials on seeds because of their phytotoxicity. The possibility of mixing some of them with fertilizers was suggested. The references cited above, while not specifically referring to our present study, laid the background for our program.

The modern program of soil treatment for controlling insects commonly found on the underground portions of corn plants became practical and economical with the advent of chlorinated hydrocarbons and the development of machinery for applying them. During the early 1940's, DDT and benzene hexachloride were extensively tested and by 1946 and 1947 reports were appearing[8, 9] dealing with the control of specific insects by their use as soil treatments. However, large amounts of DDT were required and benzene hexachloride, even in small amounts, affected the flavor of the products on which it was used. There are frequent reports of tests with other chlorinated hydrocarbons such as lindane, aldrin, chlordane, heptachlor, and dieldrin from 1950 to the present.

The earliest tests in Illinois with chlorinated hydrocarbons applied to the soil were in 1945 and 1946 (unpublished data) when DDT was mixed with soil in a test for control of the grape colaspis. Further tests

* Superior figures refer to literature cited.

with DDT, lindane, aldrin, chlordane, heptachlor, dieldrin, endrin, and toxaphene were carried out. The early tests were with sprays applied broadcast and disked in just ahead of planting. During more recent years we have transferred to the use of granules. These have been applied either broadcast and disked in just ahead of planting or dropped in the seed furrow just behind the planter shoe so that they were covered with the seed.

Many of the early tests were failures or unsatisfactory. In some cases infestations failed to develop. In others insecticides were unsatisfactory because of phytotoxicity or because the amount of insecticide required to produce results was uneconomical. As a result of the work reported in Illinois Bulletin 641,[1] we settled on the use of aldrin and heptachlor, either broadcast at the rate of 1.5 pounds of technical insecticide per acre or 1.0 pound of the chemical as a row application. These materials were adopted because of the immediate effectiveness of the insecticides themselves and their epoxides,[7] and also because they were relatively inexpensive.

Methods

No one of the soil-infesting insects previously mentioned is predominantly important at all times, but any one or more may be of great importance in any single year. The range of soil and climatic conditions within the state is wide and cropping practices are varied. Certain insects that migrate from the south may invade the state any year when conditions for their development are favorable in the south. The result is that there is a problem with some insect somewhere in the state almost every year.[2]

As a result of all these conditions we decided that the problem of one insect in one place could not be attacked, but that the entire soil-insect complex on corn would have to be studied over a wide area. This resulted in a study based on cooperating-farmer tests. A pilot test in 1953 encouraged us to proceed further along these lines.

In the early years we supplied the farmers with insecticides and they in turn agreed to apply them as directed and to leave an untreated area on one or more of their fields. In later years we usually secured cooperators from among farmers who were applying insecticide as a normal practice and who were willing to leave untreated areas in treated fields as study areas. Treatments were applied under a wide range of conditions and some unpredicted variables occurred. This report summarizes as many of the results as practicable. A report on five years of these studies has been published previously.[1]

Because of variable insect infestation and other conditions, we do not have equal numbers of observations in many of the categories studied. In the same summary of data many tests may be represented under one condition and few under another. The number of observations, which are given in the tables, must be considered in evaluating the data.

Data

For each field we attempted to secure data on kind and amount of insecticide used, method of application, whether seed treatments were used, crop rotations, kinds of insects present and their abundance, plant populations resulting from treatments, and resulting yields. Few records of the abundance of seed-corn maggot, seed-corn beetle, and cutworms were obtained because of the short period of time during which they are present. We believe that plant population counts indicate to a great extent the results of control of these insects, but we realize that other variables may exist.

During the early years of the study, data on the abundance of insects were obtained by digging hills of corn and thoroughly examining the roots and surrounding soil, and later, as planting practices of Illinois farmers changed, by digging individual plants in most tests. Early season (May and June) diggings usually included the entire root system. Diggings for rootworm records, made usually during July, included about a square foot of area 7 to 8 inches deep, and did not include the entire root system. Diggings were made at random within the untreated and treated areas of fields except that where no insects were found in the untreated area, diggings were not made in the treated area of a field. At least 5 samples and sometimes 10 were taken in each untreated and treated area of an infested field. The data are recorded as numbers of insects per 5 hills or plants, except that the cornfield ant and corn-root aphid are shown as nests or colonies.

Plant population data are the result of counting 25 hills or 83⅓ feet of row in each of 6 rows in each treatment, each count being started 10 steps into a field beyond the end of the previous one and in an adjacent row. This resulted in sampling slightly less than 1/25 acre and extended approximately 40 rods into the field. A statistical study indicated that 6 replicates would secure as accurate data as a larger count.

Yield data were obtained during the early years by hand-picking five samples, each 2 rows by 10 hills (or 33⅓ feet), at randomly selected areas in each treatment. Since 1959 most yield data were secured by machine-picking four or eight rows the entire length of a field.

Results of Planting Time Treatments

At the start of this study, all treatments were applied on plowed ground. Broadcast treatments were applied during final preparation for planting and promptly disked into the top soil. In row treatments the insecticide was applied in the seed furrow at the rear of the planter shoe and covered by the soil dropping over the seed. The results of the treatments applied in either of these ways follow.

INSECT CONTROL

The basic problem involved in this program is control of the insects present by the treatments involved and their effect on development and productivity of the corn plants. Overall control of the insects, which we were able to determine by digging and actual count, is given in Table 1. The first part of this table reports control of the specified insects by all dosages of aldrin and heptachlor including broadcast or row application and both sprays or granules. The apparent superiority of heptachlor is probably due to the disparity in the numbers of tests involved — 265 for aldrin and 51 for heptachlor, a ratio of about 5 to 1. The aldrin was thus exposed to many more tests where the likelihood of unfavorable conditions could have existed. For instance, control of wireworms would have been identical except for the counts in two of

Table 1. — Control of Insects by All Treatments With Aldrin or Heptachlor

Insect	Number tests insect present	Percent control	Number tests insect present	Percent control	Number tests insect present	Percent control
	Aldrin (265 tests)		**Heptachlor** (51 tests)		**Both insecticides** (316 tests)	
Wireworms[a]	184	77.7	37	86.8	221	79.5
White grubs[a]	90	79.8	18	88.2	108	81.5
Cornfield ants[b]	125	71.0	23	97.1	148	74.5
Corn-root aphids[b]	75	71.7	12	93.8	87	74.1
Corn rootworms[a]	76	84.5	22	88.1	98	85.4
Grape colaspis	36	70.4	9	75.5	45	71.1
	Broadcast (206 tests)		**Row** (110 tests)		**Both types of application** (316 tests)	
Wireworms[a]	150	82.5	71	72.2	221	79.5
White grubs[a]	75	85.9	33	73.2	108	81.5
Cornfield ants[b]	88	84.5	60	62.4	148	74.5
Corn-root aphids[b]	53	81.9	34	63.3	87	74.1
Corn rootworms[a]	65	88.3	33	75.2	98	85.4
Grape colaspis	25	83.3	20	60.4	45	71.1

[a] More than one species included in these categories.
[b] Nests or colonies.

the fields where aldrin, but not heptachlor, was used. Not shown in this part of the table is the fact that the insecticide was applied broadcast on 94 percent of the heptachlor tests and only 40 percent of the aldrin tests. As is mentioned below, controls were better with broadcast than with row treatments.

It appears that broadcast application was uniformly superior to row application, disregarding what concentration of either insecticide was applied. While these data are somewhat biased by the fact that there were 206 tests with treatment applied broadcast and 110 tests with row application, a ratio of approximately 2 to 1, they are not biased to the same extent as the insecticide comparison and are considered to be reliable.

Some of the inequalities just mentioned are smoothed by tabular material in Table 2 showing the results obtained where both insecticides were applied in the same field by the same equipment and operator and in the same form. Here we find that in 34 fields heptachlor appeared to be somewhat, but not outstandingly, superior in controlling four of the six insects when the two insecticides are compared. Aldrin produced the best results with the other two insects. The data also show that, except in one case, broadcast was equal or superior to row application. Here again wireworm control would have been identical for the two methods except for one field where the aldrin treatment failed to control these insects.

Table 2. — Insect Control Where Aldrin and Heptachlor Were Used in the Same Field

Insect	Number fields insect present	Percent control	Percent control
		Aldrin (34 fields)	**Heptachlor** (34 fields)
Wireworms[a]	24	69.4	84.7
White grubs[a]	14	82.4	90.1
Cornfield ants[b]	14	87.5	95.5
Corn-root aphids[b]	8	88.9	90.0
Corn rootworms[a]	15	91.4	86.9
Grape colaspis	4	57.1	42.9
		Broadcast (14 fields)	**Row** (14 fields)
Wireworms[a]	9	75.0	85.0
White grubs[a]	2	100.0	100.0
Cornfield ants[b]	7	87.5	75.0
Corn-root aphids[b]	3	50.0	0
Corn rootworms[a]	8	77.3	72.5
Grape colaspis	4	57.1	30.4

[a] More than one species included in these categories.
[b] Nests or colonies.

Table 3. — Increases in Plant Populations Due to All Treatments With Aldrin or Heptachlor

Year	Number tests involved	Increased plants per acre		Number tests involved	Increased plants per acre		Number tests involved	Increased plants per acre	
		Number	Percent		Number	Percent		Number	Percent
	Aldrin (366,597 plants)			**Heptachlor** (84,023 plants)			**Both insecticides** (450,620 plants)		
1954	99	752	7.1	7	859	8.0	106	760	7.1
1955	74	600	5.1	18	469	4.0	92	574	4.9
1956	58	676	5.9	21	865	7.9	79	726	6.4
1957	35	692	5.6	17	671	5.5	52	686	5.6
1958	18	786	6.2	12	726	5.8	30	762	6.0
1959	41	786	7.1	6	1218	9.0	47	886	7.4
1960	27	660	5.2	3	907	7.2	30	686	5.4
1961	17	734	6.1	3	341	3.8	20	676	5.9
1962	11	393	2.7	2	432	2.9	13	398	2.7
1963	18	249	1.9	1	157	1.2	19	246	1.9
1954–1963	398	686	5.8	90	721	6.1	488	686	5.8
	Broadcast (299,125 plants)			**Row** (151,495 plants)			**Both types of application** (450,620 plants)		
1954	81	776	7.4	25	713	6.3	106	760	7.1
1955	60	647	5.4	32	443	3.9	92	574	4.9
1956	50	920	8.4	29	396	3.3	79	726	6.4
1957	42	739	6.0	10	466	3.6	52	686	5.6
1958	22	820	6.8	8	600	4.2	30	762	6.0
1959	24	1053	8.9	23	713	5.8	47	886	7.4
1960	22	747	6.1	8	516	3.8	30	686	5.4
1961	14	770	7.2	6	451	3.3	20	676	5.9
1962	7	524	3.6	6	254	1.7	13	398	2.7
1963	7	220	1.6	12	257	2.0	19	246	1.9
1954–1963	329	773	6.7	159	508	4.1	488	686	5.8

PLANT POPULATIONS

For insects whose abundance we were unable to measure by digging, we used counts of plant populations in treated and untreated areas of fields as a measurement of control. Although other factors are involved, this is the best measurement we have of control of the seed-corn beetles, the seed-corn maggot, and the black cutworm.

Uniform plant counts were made on a total of 488 test areas, of which 398 had been treated with aldrin and 90 with heptachlor (Table 3). With these counts there was a small difference apparently favoring the heptachlor, although the results varied from year to year. Here again, the exclusion of one 1959 field would have made the aldrin and heptachlor percentages almost identical. Broadcast applications (329 tests) were shown to be superior to row treatments (159 tests).

Table 4. — Increases in Plant Populations Due to Treatments With Aldrin and Heptachlor When Compared in the Same Field

Year[a]	Number of tests	Increased plants per acre					
		Number	Percent	Number	Percent	Number	Percent
		Aldrin (51,766 plants)		**Heptachlor** (51,666 plants)		**Both Insecticides** (103,432 plants)	
1954	4	778	7.7	773	7.7	776	7.7
1955	12	1,082	8.7	660	5.3	870	7.0
1956	19	943	8.5	909	8.2	925	8.4
1957	10	424	3.5	909	7.5	668	5.5
1958	9	713	5.9	888	7.3	799	6.6
1959	1	1,258	8.4	1,386	9.6	1,349	9.0
1960–1962	1	655	6.2	−105	−1.0	275	2.6
1954–1962	56	833	7.1	833	7.1	833	7.1
		Broadcast (22,156 plants)		**Row** (21,832 plants)		**Both types of application** (43,988 plants)	
1954	6	912	7.6	508	4.2	710	5.9
1955	1	262	2.0	550	4.2	406	3.1
1958	2	1,087	8.2	917	6.9	1,003	7.6
1959	4	891	7.2	262	2.1	576	4.7
1960–1962	9	422	3.1	427	3.2	427	3.2
1954–1962	22	694	5.4	469	3.7	582	4.5

[a] No comparisons in years not recorded.

Plant counts made on 56 tests where both aldrin and heptachlor were used in the same field (Table 4) showed no difference between the two insecticides. On 22 fields where both broadcast and row treatments were used, the broadcast treatment gave the best results.

Table 5. — Increases in Yield Due to All Treatments With Aldrin or Heptachlor

Year	Number tests	Bushels per acre		Increases due to treatment		Number tests	Bushels per acre		Increases due to treatment		Number tests	Bushels per acre		Increases due to treatment	
		Treated	Check	Bushels	Percent		Treated	Check	Bushels	Percent		Treated	Check	Bushels	Percent
		Aldrin					**Heptachlor**					**Both insecticides**			
1954.....	27	75.2	72.1	3.1	4.3	2	62.5	62.1	.4	.7	29	74.3	71.4	2.9	4.0
1955.....	11	81.1	76.6	4.5	5.9	1	88.4	99.4	−11.0	−11.1	12	81.7	78.5	3.2	4.1
1956.....	7	109.1	102.2	6.9	6.8	4	93.1	90.6	2.5	2.7	11	103.3	98.0	5.3	5.4
1957.....	8	109.6	103.0	6.6	6.5	7	104.2	100.4	3.8	3.7	15	107.1	101.8	5.3	5.2
1958.....	9	104.3	89.7	14.6	16.2	4	112.8	108.4	4.4	4.0	13	106.9	95.5	11.4	11.9
1959.....	16	88.1	81.3	6.8	8.4	2	115.4	105.1	10.3	9.8	18	91.1	83.9	7.2	8.6
1960.....	8	90.3	82.6	7.7	9.3	4	96.1	82.5	13.6	16.5	12	92.2	82.6	9.6	11.7
1961.....	8	116.4	108.2	8.2	7.5	2	82.6	77.5	5.1	6.6	10	109.6	102.1	7.5	7.4
1962.....	3	112.7	120.9	−8.2	−6.8	..	....	....	...	...	3	112.7	120.9	−8.2	−6.8
1963.....	7	104.0	99.7	4.3	4.3	..	....	....	...	...	7	104.0	99.7	4.3	4.4
1954–1963	104	92.6	86.7	5.9	6.7	26	97.9	93.0	4.9	5.3	130	93.7	88.0	5.7	6.4
		Broadcast					**Row**					**Both types of application**			
1954.....	20	82.5	79.4	3.1	3.8	9	56.1	53.5	2.6	4.9	29	74.3	71.4	2.9	4.0
1955.....	6	87.9	88.4	−.5	−.5	6	75.5	68.6	6.9	10.1	12	81.7	78.5	3.2	4.1
1956.....	11	103.3	98.0	5.3	5.4	..	....	....	...	...	11	103.3	98.0	5.3	5.4
1957.....	15	107.1	101.8	5.3	5.2	..	....	....	...	...	15	107.1	101.8	5.3	5.2
1958.....	12	108.7	97.3	11.4	11.7	1	85.0	73.8	11.2	15.2	13	106.9	95.5	11.4	11.9
1959.....	10	91.6	82.5	9.1	11.0	8	90.6	85.7	4.9	5.7	18	91.1	83.9	7.2	8.6
1960.....	9	96.4	85.7	10.7	12.4	3	79.9	73.1	6.8	9.3	12	92.2	82.6	9.6	11.7
1961.....	8	104.6	96.7	7.9	8.2	2	129.5	123.5	6.0	4.9	10	109.6	102.1	7.5	7.4
1962.....	2	101.8	113.0	−11.2	−10.0	1	134.5	136.7	−2.2	−1.6	3	112.7	120.9	−8.2	−6.8
1963.....	1	90.9	90.1	.8	.9	6	106.2	101.3	4.9	4.8	7	104.0	99.7	4.3	4.4
1954–1963	94	97.2	91.2	6.0	6.6	36	84.4	79.5	4.9	6.1	130	93.7	88.0	5.7	6.4

YIELDS

Yield records were obtained on 130 tests made up of 104 areas treated with aldrin and 26 with heptachlor (Table 5). Wide variations occurred from year to year with both materials, but the aldrin treatments, with larger numbers of tests, were more uniform. The effect of a single record where there are small numbers is demonstrated in the results with heptachlor. If the one 1955 field were removed from the data, the average for heptachlor would be a gain of 5.6 bushels or 6.0 percent. A small but not economically important difference existed between broadcast and row applications in favor of the broadcast method.

When aldrin and heptachlor were used on the same 14 fields (Table 6), a wide difference in favor of aldrin was indicated. Both insecticides showed an economically profitable increase for treatment. In the six cases where broadcast and row applications were used in the same field, a worthwhile gain appeared for the broadcast over the row application.

Table 6. — Increases in Yield Due to Treatment When Aldrin and Heptachlor Were Used in Same Field

Year	Number tests	Bushels per acre		Increases due to treatment		Bushels per acre		Increases due to treatment	
		Trea.	Check	Bushels	Percent	Trea.	Check	Bushels	Percent
		Aldrin				Heptachlor			
1956.....	4	89.5	82.1	7.4	9.0	93.1	90.6	2.5	2.8
1957.....	6	103.9	96.8	7.1	7.3	100.2	96.8	3.4	3.5
1958.....	3	108.3	108.0	.3	.3	110.6	108.0	2.6	2.4
1960.....	1	77.6	63.7	13.9	21.8	74.8	63.7	11.1	17.4
1956–1960	14	98.9	92.6	6.3	6.5	98.6	95.1	3.5	3.7
		Broadcast				Row			
1959.....	2	81.5	72.6	8.9	12.3	80.5	72.6	7.9	10.9
1960.....	1	76.1	63.7	12.4	19.5	77.6	63.7	13.9	21.8
1961.....	3	133.3	125.6	7.7	6.1	130.6	124.6	6.0	4.8
1959–1961	6	106.5	97.6	8.9	9.1	105.1	97.1	8.0	8.2

Miscellaneous Data

SEED TREATMENT TESTS

Between 1953 and 1957 we encountered a number of fields where the grower used a seed treatment as well as soil treatment in various combinations. The materials used to treat the seed were usually dieldrin or aldrin, with lindane used in a few cases. In some fields both seed and soil treatments were used on the same area.

Table 7. — Comparisons of Various Combinations of Seed Treatments With Aldrin or Heptachlor

	Seed treatment over check		Soil treatment over check		Soil treatment over seed treatment		Seed treatment plus soil treatment over					
							Check		Seed treatment		Soil treatment	
	Number of tests	Percent increase	Number of tests	Percent increase	Number of tests	Percent increase	Number of tests	Percent increase	Number of tests	Percent increase	Number of tests	Percent increase
Control of:												
Wireworms	10	27.5	8	55.0	..	...	3	83.3	..	...	..	...
White grubs	11	31.7	10	75.0	..	...	..	...	..	...	..	...
Cornfield ants[a]	5	66.7	4	100.0	..	...	..	...	..	...	..	...
Corn-root aphids[a]	3	50.0	2	100.0	..	...	..	...	..	...	..	...
Rootworms	2	19.9	1	100.0	..	...	2	84.2	..	...	..	...
Grape colaspis	3	56.0	3	92.0	..	...	..	...	..	...	..	...
Increase in number of plants surviving	17	−1.9	17	6.6	18	9.3	4	−2.9	28	5.3	4	7.8
Increase in bushels per acre	3	2.2	4	10.2	..	...	..	...	8	3.4	1	−8.6

[a] Nests or colonies.

The results obtained on the fields which we were able to check are shown in Table 7. In all cases the seed and soil treatments were in the same field. It is apparent that seed treatments were not very successful. When compared with no treatment, the seed treatment did not give insect control comparable to soil treatment. Plant counts showed a considerable increase for soil treatment compared with a small reduction for seed treatment. At least some of the poor results with seed treatment were due to mechanical difficulties.

EFFECT ON EARTHWORMS

During the first three years of this study we recorded annual earthworm populations for several fields. The data collected from 37 fields are recorded in Table 8. Since except for one field there were consistently more earthworms in treated soil than in untreated soil during this period, these records were discontinued.

Table 8. — Effect of Soil Treatments With Aldrin or Heptachlor on Earthworm Populations

Treatment	Number fields	Number of worms found on		Ratio of treated as compared to check
		Treated area	Check	
Aldrin broadcast treated	15	134	110	1.22:1
Heptachlor broadcast treated	8	82	68	1.21:1
Aldrin row treated	13	146	136	1.07:1
Heptachlor row treated	1	0	1	.....
All fields	37	362	315	1.15:1

Results of Treatment During Winter and Spring

By the time growers began to adopt the practice of soil treatment with insecticide quite generally, we frequently were told that it involved a considerable increase in the time and labor involved at a critical stage of farm operations. We therefore investigated the possibility of making these applications during other seasons of the year. A few preliminary tests were conducted in 1956, with more extensive tests started in 1957. At first we included treatments applied during the fall (prior to December 1) season, but these were soon abandoned due to failure to produce satisfactory results and to the danger of loss of insecticide during warm fall weather. Applications made during the winter and spring months were continued until 1963.

The insecticide was applied either with ground equipment or by airplane. It was frequently incorporated into or on fertilizers being applied at the same time. Applications were most often made on stubble of corn, soybeans, or small grain, or on sod ground, but about 30 percent were made to plowed ground. All of these were applied broadcast. We established arbitrary dates for these seasons as: winter, December 1 to March 15; and spring, March 16 to April 15. Applications made after the April 15 date were considered planting time preparation.

The results obtained with all treatments in winter and spring are compared with planting time treatments during the same years in Tables 9, 10, and 11. In Table 9 the insect control results are given as totals for the seven years. It is immediately apparent that the winter and spring treatments did not result in control of the cornfield ant and the corn-root aphid when all treatment conditions were combined. However, these insects are not a major problem in Illinois.[2] Control of the other insects was nearly equal at all periods of treatment except in some instances where there was a great disparity in the numbers of tests involved. In general, winter and spring treatments more nearly approached the effectiveness of broadcast rather than row treatments at planting time. Smaller numbers of fields were involved with grape colaspis.

Plant population counts (Table 10) showed that broadcast applications at planting time gave the best results. These were better than winter applications, and winter applications were better than spring applications. Row applications at planting time gave the least increase in the number of plants. This could be summarized as: Broadcast at planting time > winter > spring > row at planting time. However, a 1 percent difference would result in an increase of only 160 plants per acre in a field with 16,000 plants per acre. Here the greatest overall spread is between broadcast and row applications which is equivalent to 384 plants per acre in the suggested 16,000-plant field.

Yield data comparing all winter and spring treatments with planting time treatments show that the percent increase in yield for broadcast application at planting time is approximately equal to the increase for winter applications (Table 11). This was somewhat better than spring applications, and these were all better than row applications at planting time. These data can be briefly summarized as: Broadcast at planting time = winter > spring > row at planting time. It should be noted that a 1 percent difference here means only 1 bushel per acre with 100 bushel corn. The only economically important difference is with the row applications at planting time.

Table 9. — Insect Control for Treatments of Aldrin or Heptachlor Applied at Various Seasons, 1957-1963[a]

Treatment	Total number tests		Wireworms		White grubs		Cornfield ants		Corn-root aphids		Rootworms		Grape colaspis	
	Treated	Infested	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control
Planting time:														
Broadcast	127	93	66	82.4	20	91.3	53	84.5	34	78.4	33	94.1	14	80.2
Row	71	53	34	76.2	10	58.3	29	57.1	17	61.8	23	68.2	14	56.3
Both	198	146	100	80.5	30	84.5	82	73.6	51	71.8	56	85.8	28	66.3
Winter[c]	98	75	51	79.4	9	84.6	46	41.3	38	10.2	31	75.4	10	66.0
Spring[d]	48	43	25	89.4	7	100.0	28	13.6	26	20.4	27	91.7	2	100.0
Winter and spring[c, d]	146	118	76	82.7	16	93.8	74	27.9	64	15.5	58	83.6	12	67.3

[a] Includes 1956-57 winter and spring season.
[b] Number of tests when each insect was present.
[c] December 1 through March 15.
[d] March 16 through April 15.

Table 10. — Plant Populations When Treatments of Aldrin or Heptachlor Were Applied at Various Seasons, 1957-1963

Year	Number tests	Increased plants per acre for treatment		Number tests	Increased plants per acre for treatment		Number tests	Increased plants per acre for treatment	
		Number	Percent		Number	Percent		Number	Percent
	Broadcast at planting time (132,458 plants)			**Row at planting time (74,300 plants)**			**Broadcast and row (206,758 plants)**		
1957	42	737	6.0	10	466	3.6	52	685	5.6
1958	22	822	6.8	8	632	4.4	30	771	6.1
1959	24	1054	8.9	23	711	5.8	47	886	7.4
1960	22	745	6.1	8	517	3.8	30	685	5.4
1961	14	771	7.2	6	450	3.3	20	675	5.9
1962	7	524	3.6	6	253	1.7	13	399	2.7
1963	7	221	1.6	12	258	2.1	19	244	1.9
1957–1963	138	773	6.3	73	514	3.9	211	684	5.5
	Winter (109,129 plants)			**Spring (46,367 plants)**			**Winter and spring (155,496 plants)**		
1956–57	5	796	5.4	3	908	6.7	5	796	5.4
1957–58	..	...	...	11	860	5.9	3	908	6.7
1958–59	..	...	...	12	406	3.3	11	860	5.9
1959–60	13	905	7.0	2	406	3.1	25	665	5.3
1960–61	51	704	5.3	14	526	3.8	53	692	5.2
1961–62	28	696	5.0	2	603	4.2	42	639	4.6
1962–63	5	545	3.6	..	...	...	7	561	3.8
1957–1963	102	724	5.3	44	601	4.4	146	687	5.0

Table 11. — Yields When Treatments of Aldrin or Heptachlor Were Applied at Various Seasons, 1957-1963

Year	Broadcast treatment at planting time					Row treatment at planting time					Both treatments				
	Number tests	Bushels per acre		Increase for treatment		Number tests	Bushels per acre		Increase for treatment		Number tests	Bushels per acre		Increase for treatment	
		Treated	Check	Bushels	Percent		Treated	Check	Bushels	Percent		Treated	Check	Bushels	Percent
1957	15	107.1	101.8	5.3	5.2	0	....	....	...	...	15	107.1	101.8	5.3	5.2
1958	12	108.7	97.3	11.4	11.7	1	85.0	73.8	11.2	15.2	13	106.9	95.5	11.4	12.0
1959	10	91.6	82.5	9.1	11.1	8	90.6	85.7	4.9	5.7	18	91.1	83.9	7.2	8.6
1960	9	96.4	85.7	10.7	12.4	3	79.9	73.1	6.8	9.3	12	92.2	82.6	9.6	11.7
1961	8	104.6	96.7	7.9	8.2	2	129.5	123.5	6.0	4.9	10	109.6	102.1	7.5	7.4
1962	2	101.8	113.0	−11.2	−10.0	1	134.5	136.7	−2.2	−1.6	3	112.7	120.9	−8.2	−6.8
1963	1	90.9	90.1	.8	.9	6	106.2	101.3	4.9	4.9	7	104.0	99.7	4.3	4.3
1957–1963	57	102.2	94.4	7.8	8.3	21	99.0	93.8	5.2	5.5	78	101.4	94.2	7.2	7.6
	Winter					Spring					Winter and spring				
1956–57	3	104.4	95.8	8.6	9.0	0	....	....	...	...	3	104.4	95.8	8.6	9.0
1957–58	2	79.8	68.3	11.5	16.8	2	95.4	70.8	24.6	34.7	4	87.6	69.5	18.1	25.9
1958–59	0	....	....	...	...	7	117.8	108.6	9.2	8.5	7	117.8	108.6	9.2	8.5
1959–60	6	118.0	110.2	7.8	7.1	4	101.3	95.2	6.1	6.4	10	112.3	104.2	7.1	6.8
1960–61	26	115.6	108.5	7.1	6.5	0	....	....	...	...	26	115.6	108.5	7.1	6.5
1961–62	14	109.5	99.5	10.0	10.1	7	109.1	108.1	1.0	.9	21	109.4	102.4	7.0	6.9
1962–63	0	....	....	....	....	0	....	....	...	...	0	....	....	...	...
1956–1963	51	112.1	103.9	8.2	7.9	20	109.2	102.0	7.2	7.1	71	111.3	103.4	7.9	7.7

Ground Applications Compared With Airplane Applications

Insect control data in Table 12 indicate that ground application gave better results with two of the insects while airplane applications gave better results with the other four insects, including the cornfield ant and corn-root aphid. Table 15 shows this to be due to the inclusion in these figures of treatments applied to plowed ground. The use of either type of application produced good control of all but cornfield ants and corn-root aphids.

There was little difference between the two methods in the average increase in the number of plants (Table 13). It would amount to only 128 plants per acre in the theoretical 16,000 plant field previously used

Table 12. — Insect Control for Ground and Airplane Treatments With Aldrin or Heptachlor Applied During Winter and Spring, 1959-1962[a]

Insect	Number tests insect present	Percent control	Number tests insect present	Percent control
	Ground equipment treated (22 tests)		Airplane treated (74 tests)	
Wireworms	18	87.9	55	79.4
White grubs	4	75.0	11	96.3
Cornfield ants	17	15.4	53	26.7
Corn-root aphids	16	0	46	19.7
Rootworms	14	92.5	37	80.5
Grape colaspis	5	63.9	7	75.0

[a] December 1 to April 15.

Table 13. — Effect on Plant Populations of Ground and Airplane Treatments With Aldrin or Heptachlor Applied During Winter and Spring, 1959-1962[a]

Year	Number tests	Increase for treatment		Number tests	Increase for treatment	
		Plants per acre	Percent		Plants per acre	Percent
	Ground equipment treated			Airplane treated		
1958–59	6	1302	8.2	5	330	2.5
1959–60	5	686	5.9	20	660	5.1
1960–61	14	584	4.4	39	731	5.5
1961–62	9	152	1.1	33	773	5.5
1958–1962	34	610	4.5	97	710	5.3

[a] December 1 to April 15.

as an example. Airplane treatment on 45 fields produced an 8.2 percent increase in yield, whereas ground treatment on 18 fields showed only a 3.7 percent increase (Table 14). During the 1961-62 season the results varied widely. Three of the ground applied fields showed considerable losses. The exclusion of these data would show a 7.0 percent increase for airplane and 6.6 percent increase for ground application. There were no comparisons during the years not shown in these tables.

Table 14. — Effect on Yield of Ground and Airplane Treatments With Aldrin or Heptachlor Applied During Winter and Spring, 1959-1962[a]

Year	Number tests	Increase for treatment		Number tests	Increase for treatment	
		Bushels per acre	Percent		Bushels per acre	Percent
	Ground equipment treated			Airplane treated		
1958–59	4	9.2	8.4	3	9.2	8.6
1959–60	3	9.5	8.8	7	6.1	5.9
1960–61	5	4.7	4.1	20	7.6	7.1
1961–62	6	−2.6	−2.4	15	10.9	9.9
1958–1962	18	4.0	3.7	45	8.6	8.2

[a] December 1 to April 15.

Ground Cover When Treated

The data for winter and spring treatments were also tabulated as to whether the application was made on stubble (corn, small grain, or soybeans), sod (grass, legume, or mixed hay), or plowed ground.

An outstanding feature of the insect control data (Table 15) is that treatment on plowed land controlled the cornfield ant and the corn-root aphid, but on stubble or sod land it did not. Treating sod land is not shown to be as satisfactory as treating the other habitats. Spring treatments were usually superior to winter treatments. In most tests application with ground equipment was somewhat better than with airplane. However, the airplane treatments produced satisfactory controls in practically all tests.

Plant population data in Table 16 indicate that the best results were obtained by treating plowed land in the winter and stubble land in the spring. Treating sod land at either time resulted in poorer results than treating stubble land.

Table 15. — Effect Upon Insect Control of Ground Cover Present When Fields Were Treated With Aldrin or Heptachlor During Winter and Spring Seasons, 1957-1963[a]

Ground cover treated	Total number tests		Wireworms		White grubs		Cornfield ants		Corn-root aphids		Rootworms		Grape colaspis	
	Treated	Infested	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control	Number tests[b]	Percent control
Applied in winter or spring														
Stubble[c]														
Winter[e]	56	43	29	74.2	7	90.9	34	46.0	29	20.0	22	74.8	1	100.0
Spring[f]	34	31	13	90.5	5	100.0	20	0	19	11.6	25	91.6	1	100.0
All	90	74	42	80.6	12	96.3	54	22.6	48	15.9	47	83.4	2	100.0
Sod[d]														
Winter[e]	16	12	9	87.5	1	0	6	0	6	0	1	100.0	7	60.0
Spring[f]	7	7	7	80.0	1	100.0	7	53.8	6	37.5	0	....	1	100.0
All	23	19	16	83.9	2	66.7	13	21.1	12	0	1	100.0	8	61.0
Plowed ground														
Winter[e]	26	20	13	83.3	1	100.0	6	85.7	2	100.0	8	85.4	2	88.9
Spring[f]	7	5	5	100.0	1	100.0	1	100.0	2	66.7	2	100.0	0	....
All	33	25	18	85.7	2	100.0	7	90.0	4	80.0	10	90.0	2	88.9
Applied with ground equipment or with airplane														
Stubble[g]														
Ground	33	27	15	86.0	3	50.0	17	12.5	16	0	19	90.5	1	100.0
Plane	57	47	27	75.9	9	100.0	37	26.1	32	25.0	28	79.9	1	100.0
Sod[g]														
Ground	8	6	4	100.0	1	100.0	2	75.0	1	0	1	100.0	4	62.9
Plane	15	13	12	73.7	1	0	11	6.7	11	0	0	....	4	50.0
Plowed ground[g]														
Ground	5	3	2	100.0	1	100.0	2	100.0	2	66.7	1	0	..	....
Plane	28	22	16	84.7	1	100.0	5	83.3	2	100.0	9	91.4	2	88.9

[a] Includes 1956-57 winter and spring seasons.
[b] Number of tests when each insect was present.
[c] Stubble of corn, soybean, or small grain.
[d] All sod land, grass, legume, or mixtures.
[e] December 1 through March 15.
[f] March 16 through April 15.
[g] Total of winter and spring seasons.

Table 16. — Effect Upon Plant Populations of Ground Cover Present When Field Were Treated With Aldrin or Heptachlor During Winter and Spring Seasons, 1957-1963[a]

Ground cover treated		Stubble[b]			Sod land[c]			Plowed land		
Treated	Total number tests	Number tests	Increase in number plants per acre	Percent increase	Number tests	Increase in number plants per acre	Percent increase	Number tests	Increase in number plants per acre	Percent increase
Winter season[d]	100	53	679	5.0	16	343	2.7	31	990	7.1
Spring season[e]	44	32	707	5.2	5	592	3.9	7	155	1.2
Winter plus spring	144	85	689	5.1	21	403	3.0	38	836	6.1

[a] Includes 1956-57 winter and spring seasons.
[b] Stubble of corn, soybeans, and small grain.
[c] All sod land, grass, legumes, or mixtures.
[d] December 1 through March 15.
[e] March 16 through April 15.

Table 17. — Effect Upon Yield of Ground Cover Present When Fields Were Treated With Aldrin or Heptachlor During Winter and Spring Seasons, 1957-1963[a]

Ground cover treated		Stubble[b]			Sod land[c]			Plowed land		
Treated	Total number tests	Number tests	Increase in bushels per acre	Percent increase	Number tests	Increase in bushels per acre	Percent increase	Number tests	Increase in bushels per acre	Percent increase
Winter season[d]	52	34	6.8	6.6	4	6.3	5.9	14	12.5	11.8
Spring season[e]	21	18	6.1	5.9	2	9.4	8.5	1	22.0	24.3
Winter plus spring	73	52	6.5	6.2	6	7.4	6.8	15	13.2	12.5

[a] Includes 1956-57 winter and spring treatments.
[b] Stubble of corn, soybeans, and small grain.
[c] All sod land, grass, legumes, or mixtures.
[d] December 1 through March 15.
[e] March 16 through April 15.

Treating during winter or spring on plowed land resulted in higher yields than treating either stubble or sod land. In this comparison sod land treatments were as good as or better than stubble land treatments, but with only six tests on the sod land (Table 17).

In these categories the important factor is probably the post-application shading and protection of the granules from exposure to sun and wind so that there is less volatilization and loss of insecticide before plowing. During the winter the soil and insecticide on plowed land is usually washed from the peak of the furrows into the hollows between and the insecticide is well covered. With spring application this does not have as much time to occur. Stubble usually stands 6 to 8 inches tall and offers shading of the ground and protection from wind, whereas sod land is frequently relatively bare. The overall picture indicates that the best results might be expected following treatment of plowed land.

Persistence of Residues in Soil

Aldrin and heptachlor are often characterized as broad-spectrum insecticides that leave residues which persist long after the chemicals are applied. On the basis of this premise it is frequently assumed or implied that following their use there is little or no diminution in the magnitude of the residues produced and therefore that repeated applications would result in the accumulation of residues of these chemicals and their degradation products which would eventually prove hazardous to man, adversely affect desirable forms of plant and animal life, and possibly sterilize the soil.

Rather extensive studies of soil residues conducted in Illinois over a period of years, including many of the fields represented in this study, reveal that scientific data fail to support such a premise. On the basis of these studies, the results of which have been published,[4] it was concluded that under Illinois conditions the probability was remote that annual applications of aldrin over a period of 10 years or more would result in accumulations in excess of the annual application rate. A study of 35 fields with well-documented case histories supports this conclusion.

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