Insecticidal Control of
UNDERGROUND INSECTS OF CORN

A report of a 5-year study

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Bulletin 641

UNIVERSITY OF ILLINOIS · AGRICULTURAL EXPERIMENT STATION
in cooperation with the ILLINOIS NATURAL HISTORY SURVEY
and the U. S. DEPARTMENT OF AGRICULTURE

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This bulletin was prepared by J. H. Bigger, Entomologist, Illinois Natural History Survey, and R. A. Blanchard, Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture. The authors gratefully acknowledge the assistance of the many farm advisers and farm operators without whose cooperation this study could not have been made. The study was supported in part by Research and Marketing Act funds allocated to North Central project 19, "Pesticide Hazards."

Urbana, Illinois April, 1959

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station

CONTROL OF UNDERGROUND INSECTS OF CORN

J. H. Bigger and R. A. Blanchard

THE ATTACKS of underground insects on corn have been a problem in Illinois from the time that corn was first grown on a large scale in this state. Entomologists have constantly sought means of controlling these pests, but it was not until the 1940's that control became practical and economical.

Underground insects are especially difficult to study, because it is usually necessary to destroy their habitat in order to determine their presence and the extent of the damage they have done. Therefore the only feasible method of attacking these insects is the use of preventive measures. The purpose of this bulletin is to report the results of four years of investigation into control of these insects.

The underground parts of corn plants are subject to the attacks of underground insects from the time the seeds are planted until the plants die or mature.

Certain species attack only the seed. They are seed-corn maggot, *Hylemya cilicrura* (Rond.), and the two seed-corn beetles, *Agonoderus lecontei* Chan., and *Clivina impressifons* Lec. Others attack only the roots of the plants. This group includes the 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 maidi-radicis* (Forbes). Wireworms, *Elateridae,* may attack either the seeds, roots, or base of the stalk, and black cutworms, *Agrotis ypsilon* (Rott.) attack the stem either underground or at the soil surface. All these insects are particularly annoying pests, because their inroads on the plants are hidden until the damage has been done and it is usually not observable until too late to apply control measures.

HISTORY OF INVESTIGATIONS AND REVIEW OF LITERATURE

For almost a century, entomologists have constantly sought some means of preventing damage from the group of soil-inhabiting, corn-attacking insects that would not interfere with farm practices, that would be acceptable to farm operators, and that would be economical to use. Early in the investigations it was determined that variations in cultural practices, such as rotations, time of plowing, time and intensity of cultivation, time of seeding, and similar procedures would greatly reduce damage. These measures, however, were unpopular with farmers because they interfered with established farm practices and often caused serious labor-load problems.

In 1917, Hinds,[7*] referring to soil treatments for control of grape phylloxera in France, reported that by 1863 more than 200,000 acres of vines were being treated annually with carbon bisulfide for this pest. In 1907, Smith[9] recommended placing this insecticide into the soil around the roots of plants to control cabbage maggot, and in 1909 Newell[8] recommended it as a soil treatment to control the Argentine ant. In 1926, Davis[1] recommended using carbon bisulfide in the soil of lawns for control of white grub. During the 1907-1926 period, many other materials were tested, but none were consistently recommended. Carbon bisulfide is very expensive to use as a soil treatment, explosive when mixed with air, and dangerous to handle. Arsenic compounds were mixed in soil for white grub control very successfully, but their expensiveness precluded extensive use of them and similar materials.

The possible use of repellents applied to seed was investigated in Illinois as early as 1905 and 1906.[2] At that time, 38 or more materials were used, of which the following are typical of groups: kerosene, turpentine, mustard, oil of lemon, flowers of sulfur, copper sulfate, and Scalecide. By 1915,[3] however, recommendations stressed the use of cultural practices and farmers were warned not to use the previously tested materials in direct contact with seed. It was suggested, however, that they might be mixed with fertilizer or similar substances.

Soil treatment for control of insects commonly found on the roots of corn did not become practical and economical until the introduction of chlorinated hydrocarbon insecticides and the development of machinery that was adequate for applying them. During the early 1940's DDT and benzene hexachloride were extensively tested. By 1946 and 1947, reports were appearing[5, 6] dealing with control of the specific insects of particular interest in this study. Effective control of wireworms and southern corn rootworms was being obtained with DDT and benzene hexachloride. Large amounts of DDT were required and its action was slow. Benzene hexachloride was used in small amounts, but imparted a flavor, especially to tubers of any sort. Reports of the use of these materials as well as lindane, aldrin, chlordane, heptachlor, parathion, and dieldrin are frequent from 1950 to the present.

The earliest test in Illinois with a chlorinated hydrocarbon applied to the soil was in 1945 and 1946 (unpublished data) when DDT was

* Superior figures refer to literature cited.

mixed in fertilizer in a test for control of grape colaspis. Infestation was low and results were not satisfactory. Further tests, including the use of DDT, lindane, aldrin, chlordane, heptachlor, dieldrin, endrin, and toxaphene have been carried out periodically until the present. During the earlier years, these were field tests in which one or more insecticides were applied broadcast and disked in ahead of planting, but during the later years of this period, they included granular insecticides and row treatments. Because of various conditions, many of these tests were failures. In some cases, infestations failed to develop in the fields. In others, the insecticides were unsatisfactory because they affected germination, or because the amount of insecticide required and the methods of application were not established.

METHODS OF PROCEDURE

In Illinois there are several species of underground insects of corn, no one of which is predominantly important at all times, but any one of which may be of great importance in any single year. The range of soil and climatic conditions within the state is wide. Certain insects that migrate from the South may invade the state in seasons when conditions in the South are favorable for their development. It was 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.

Two types of tests were used — a widespread pilot test beginning in 1953 and a closely controlled test beginning in 1954. Tests similar to the pilot test conducted from 1954 through 1957 will be referred to throughout the remainder of this report as the cooperative tests and the controlled tests as the experimental.

Cooperative tests

Cooperators were secured either by supplying a grower with insecticide for one or more plots, or by locating growers who were planning to treat their fields and who were willing to leave untreated areas in them. In all cooperative tests, untreated areas were left in the fields that were treated.

When these cooperative tests began in 1953, 32 cooperators in the northern half of the state were furnished with aldrin emulsion for use as a spray or aldrin granules for mixing in fertilizers. Several of the cooperators applied materials to test plots in more than one field. In all, plots where insecticides had been applied were examined on 57 fields. Of these, however, there were 20 where the farm operator had used insecticide-treated seed in the entire field. Results of this first series of tests were so encouraging it was decided to continue the program in subsequent years throughout the state.

Following the experience of 1953, tentative recommendations were made for using either aldrin or heptachlor at rates of 1½ pounds of active ingredient per acre broadcast, or 1 pound in the row. These were the only insecticides used in the cooperative tests. During the last two years of the period, many farmers using insecticides mixed with fertilizers tended to apply less than the recommended amounts of insecticides.

The number of tests and of fields where cooperators applied insecticide in the first year of a rotation is given below.

Year	Number of tests	Number of fields
1954	103	82
1955	139	81
1956	93	64
1957	68	54

There were also a number of fields where insecticides were being applied for two successive years in a rotation. These will be considered separately.

Variations in procedure on the plots in the cooperative tests consisted principally in amounts and methods of application and occasionally in delayed coverage of insecticide. Cooperators made broadcast applications of both sprays and granules. They applied sprays broadcast as emulsions using 5 to 10 gallons of solution per acre and made row applications with sprays, or with granules using special equipment, or mixed the granules with starter fertilizer.

Experimental tests

From 1954 through 1957, the experimental plots were located on 17 fields on 5 farms — 4 farms in Champaign county and 1 in DeKalb county. These plots were of field size, each containing an untreated area left as a check. All insecticides were put on as broadcast sprays and disked in immediately. A total of 16 tests, using single applications of insecticides, was carried out on the Champaign county farms. The insecticides used in the Champaign county tests and the amounts of actual active ingredient per acre intended to be applied were:

Insecticide	*lb.*	Insecticide	*lb.*
Aldrin	1½	Chlordane	2
Heptachlor	1½	Endrin	½
Dieldrin	1	Lindane	½

Some variations from these amounts occurred. Aldrin, dieldrin, and heptachlor were used on all fields. All insecticides except chlordane were used on 11 fields and all insecticides were included in 6 tests.

All the tests in DeKalb county were on one farm where a 37-acre field planted to corn continuously from 1952 to 1957 was used. Plots on this field were treated in 1954, 1955, and 1956 with aldrin and heptachlor at the rate of 1½ pounds of actual insecticide per acre. Each year after 1954, certain previously treated plots on this field were left untreated, so that eventually there were plots treated in 1954 only, in 1954 and 1955, and in 1954, 1955, and 1956. Certain areas received no insecticide throughout this period. All plots were duplicated. Unfortunately the plots treated with aldrin in 1954 were not disked promptly and subsequent data are influenced by this fact.

In addition to the Champaign and DeKalb county tests, a test was made in Iroquois county to find out how much control of Japanese beetle could be obtained with insecticides in general use for other soil insects. In this test, the amount of control obtained with insecticides sprayed or broadcast on June 1 and disked in immediately was compared with that obtained from a heavy application of dieldrin in granular form spread in early April with an airplane.

Kinds of data

From 1953 through 1957 for most fields, the kind and amount of insecticide used, method of application, whether seed treatment was also used, the crop growing on the land the previous year, plant population, and any other variable factors that might be important were determined. For 1954 through 1957, data concerning the numbers of insects present were also secured. Determinations of infestation by such insects as seed-corn maggot, seed-corn beetle, and cutworm were very difficult to make because of the short period during which their attack occurs. Relatively few records are available on control of these insects. Most records deal with control of wireworms, white grubs, cornfield ants, corn root aphids, and northern corn rootworms.

Data on abundance of insects were obtained by digging up an area about a foot square that included a hill of corn or a corn plant and going down 8-10 inches to include all or much of the root system. Diggings were made at random within untreated and treated areas of each field. If the first 3 diggings in the untreated portion of a field failed to show insects present, the area was listed as uninfested and no data were recorded for abundance. At least 5 samples were taken from each plot in each infested field, and occasionally 10 or more.

Damage by billbugs and cutworms was recorded as percent of plants damaged. Data were obtained on plant population (stand) by counting 25 hills or 83⅓-foot lengths in each of 6 rows in each field, slightly less than 1/25th of an acre. A statistical study indicated that 6 replicates secured as accurate data as a larger count. This type of data was considered to reflect the effect of treatment on all kinds of corn insects, including those for which digging records were inadequate, and the difference between treated and untreated areas was considered the over-all value of treatment. Data concerning plant populations for all fields were obtained, but insect populations were recorded for infested fields only.

RESULTS

Insect Numbers

During 1954-1957, untreated areas in 244 cornfields, or 54 to 63 fields a year, were sampled. These samples included both those from controlled experiments of field size and those from the cooperative tests. At the time of the diggings, insect infestations were important in an average of 38 percent of the fields. The range of infestation was 32 to 54 percent. Important infestations do not necessarily represent a level of infestation high enough to be severely injurious, but represent an arbitrary minimum number per 5-hill sample and indicate a permanent population. Arbitrary numbers were at least: 2 colonies of cornfield ants or corn root aphids; 3 wireworms, white grubs, grape colaspis, or seed-corn beetles; 10 southern corn rootworms; and 20 northern corn rootworms. Infestations of cutworms and billbugs were considered important when 10 percent or more of the plants were damaged.

During the four years, insect infestations were found to be important in 92 fields (Table 1). Fifty-one fields were infested by only 1 species, 28 by 2 species, 10 by 3 species, 2 by 4 species, and 1 by 5 species. During this period, the most prevalent and widely spread injurious soil insects were wireworms, cornfield ants, corn root aphids, northern corn rootworms, and white grubs (Table 2). Other insects found were cutworms, seed-corn beetles, billbugs, southern corn rootworms, and grape colaspis. Southern corn rootworms and grape colaspis were not very abundant during the testing period, but both have been and are potentially serious pests. Infestations of northern corn rootworms have been found in the areas north of Champaign, and southern corn rootworms largely south of there. The other insects found were distributed over the entire state, distribution depending on conditions for multiplication.

To forecast damage has been impossible, but observations in this study indicate that fields in corn 2, 3, or more years, or in corn following clover-grass or alfalfa-grass mixtures are most likely to be in-

Table 1.—EFFECT OF PRECEDING CROP ON SOIL INSECT POPULATIONS: Number and Percent of Fields Infested; 244 Fields; 1954-1957

	Crop preceding first-year corn					Second-year corn	Corn three years or more	Other
	Alfalfa and grass	Clover and grass	Small grain	Soy-beans	Blue-grass			
Number of fields	32	22	33	25	14	63	46	9
Number of fields importantly infested with number of species:								
5	..	..	..	..	..	1	..	..
4	..	1	..	..	..	..	1	..
3	..	..	2	..	..	2	6	..
2	3	2	1	..	5	8	9	..
1	10	5	2	8	1	13	8	4
Total	13	8	5	8	6	24	24	4
Infestation not important, number of fields	19	14	28	17	8	39	22	5
Percent of fields infested	41	36	15	32	43	38	52	44
Percent infested with more than one species	23	37	60	0	83	37	67	0
Percent infested with one species	77	63	40	100	17	63	33	100

Table 2.—EFFECT OF PRECEDING CROP ON SOIL INSECT POPULATIONS: Percent of Fields Infested and Percent Infested by Each Species; 244 Fields; 1954-1957

Insect	Fields infested, total	Crop preceding first-year corn					Second-year corn	Corn three years or more	Other
		Alfalfa and grass	Clover and grass	Small grain	Soy-beans	Blue-grass			
Wireworms	33.6	7.6	3.3	2.2	3.3	3.3	8.7	4.3	1.1
Cornfield ants	33.6	4.3	2.2	3.3	1.1	2.2	10.9	9.8	0
Cornfield ants and corn root aphids	20.9	0	0	2.2	0	2.2	9.8	6.5	0
Northern corn rootworms	19.6	0	0	0	0	0	3.2	16.3	0
White grubs *(Phyllophaga)*	16.3	0	3.3	2.2	3.3	0	3.3	3.3	1.1
Other white grubs[a]	6.5	1.1	1.1	0	0	0	0	4.3	0
Seed-corn beetles	7.6	1.1	3.3	0	0	0	0	3.3	0
Cutworms	5.4	1.1	0	0	0	1.1	2.2	0	1.1
Billbugs	4.3	0	1.1	0	0	0	1.1	1.1	0
Southern corn rootworm	3.3	0	1.1	0	0	0	1.1	1.1	0
Grape colaspis	1.1	1.1	0	0	0	0	0	0	0
Total	....	16.3	15.4	9.9	7.7	8.8	39.3	50.0	3.3

[a] Largely *Cyclocephala.*

fested with the insects found in the digging operations (Table 2). Fields planted to corn after small grain, soybeans, or bluegrass are least likely to be seriously infested. Infestations in second-year corn sometimes carry over from previous crops.

In at least one instance, white grubs, which have a 3-year life cycle, infested both first- and second-year corn following a straight corn-soybean rotation.

In other instances, billbugs seriously damaged corn in fields planted to corn the second year as well as that planted to corn for 3 years or more. These infestations were only coincidental, however, since the billbug infestation apparently depended on nutgrass in low areas in fields and in ditches around the borders of the field. Billbugs are most often found in bottomland fields in river valleys and in old lake bottoms. The rotation is only secondary since the larvae feed on wild swamp-type plants, and the adults cause the damage by boring into the young seedlings.

According to Illinois Natural History Survey records, populations of northern corn rootworms became large enough to cause severe lodging only where corn had been grown on the same field for 3 years or more. No large reductions in yield occurred following rootworm attack. Rootworms, however, cut off the roots of the plants and cause them to lodge. Lodging makes harvesting difficult and causes considerable actual harvest loss. Counts in several fields infested with rootworms showed picker loss on untreated plots to be double that on treated plots.

Cutworms have caused serious damage in fields in corn a second year, in fields in cotton the previous year, and in corn following alfalfa-grass mixtures, or bluegrass sod. Wireworms tend to occur most often in damaging numbers in corn following a legume-grass crop, or in second-year corn. While they were frequently found in second-year corn, they were often carried over from the legumes or other plowed-up crops, since most species have a life cycle of 3 years or more. While they were found in fields in corn 3 years or more, they caused less serious damage in such fields.

Cornfield ants were found in corn following almost every crop, but colonies of corn root aphids were found associated with them most often in fields in corn 2 years or more and less often in corn following small grain or bluegrass. They were never found in corn following a legume-grass or soybean crop. Serious damage from cornfield ants and corn root aphids occurred very rarely although they were among the most numerous of the soil insects found. At one time[2] corn root aphids were rated as one of the most injurious insects on corn in Illinois. Adoption of rotations, the use of hybrid corn, increase in general fertility of the soil, or a combination of these and other factors has lessened the damage they do.

Since seed-corn beetles and seed-corn maggots damage the sprouting seed and since it was not possible to examine many fields during the early seedling stage, it was not possible to get good records on the damage they do. Losses from these insects are reflected in the counts of plant populations that will be discussed later.

Predictions of the abundance of soil insects is, for the most part, very uncertain, as should be apparent from this discussion. In many cases, farmers will have to depend on the history of particular fields on their farms, or carry out preventive control measures as a kind of crop insurance.

Insecticidal Control

Experimental tests

Soil insect infestations were not significant on several of the experimental plots, but infestations did provide some information on control of 9 insects. In a number of cases, an insect was present in only one of the tests. In these cases, apparent differences in control between insecticides are probably not significant. All tests showed that aldrin and heptachlor at 1½ pounds an acre and dieldrin at 1 pound an acre gave good control of all the insects that occurred in these plots (Table 3). Chlordane at 2 pounds an acre gave good control of wireworms, but was not as good for control of cornfield ants. The other insects did not occur in plots where chlordane was applied. Endrin and lindane at ½ pound an acre did not give good control of certain insects. At present prices, these two insecticides could not profitably be applied at much higher rates, so were not tested further.

Aldrin and heptachlor at 1½ pounds an acre, chlordane at 2 pounds, and dieldrin at 1 pound an acre controlled wireworms and white grubs for at least 2 years (Table 3). Data (not included in this report) indicated that 2 years after the insecticides were applied aldrin gave no apparent control of seed-corn maggot, while heptachlor gave 33-percent apparent control. Lindane at ½ pound an acre gave perfect carry-over control of wireworms and corn root aphids a second year, but poor control of white grubs. Endrin at ½ pound an acre gave perfect control of white grubs a second year, but poor control of wireworms, cornfield ants, corn root aphids, and grape colaspis. In a single test, aldrin and heptachlor at 1½ pounds an acre provided excellent control of grape colaspis. Lindane at the same rate proved somewhat less effective but gave good control.

In one experimental test where the insecticides were sprayed broadcast and disked in immediately before the corn was planted, aldrin,

Table 3.—CONTROL WITH INSECTICIDES: Insecticides Sprayed Broadcast and Disked In; 17 Experimental Plots; 1954-1957

Insect	Number of tests and percent of control											
	Aldrin		Heptachlor		Dieldrin		Chlordane		Endrin		Lindane	
Control the year of application												
	no.	*perct.*	*no.*	*perct.*	*no.*	*perct.*	*no.*	*perct.*	*no.*	*perct.*	*no.*	*perct.*
Wireworms	2	100	2	100	2	100	1	90	2	90	2	95
White grubs	..	...	..	...	..	...	..	...	..	...	..	...
Cornfield ants	5	94	5	83	4	93	1	67	1	67	1	100
Corn root aphids	3	100	5	100	4	100	..	...	..	...	..	...
Northern corn rootworm	..	...	..	...	..	...	..	...	..	...	..	...
Grape colaspis	1	96	1	96	1	78	..	...	1	89	1	64
Carry-over control year following application												
Wireworms	1	100	1	100	1	100	1	90	1	70	1	100
White grubs	1	100	1	100	1	100	1	100	1	100	1	63
Cornfield ants	3	58	2	83	1	0	1	0	1	67	1	67
Corn root aphids	2	50	..	...	..	...	..	...	1	0	1	100
Northern corn rootworm	3	79	2	95	1	100	1	100	1	91	1	87
Carry-over control 2 years following application; DeKalb field only												
Northern corn rootworm	2	70	2	94	..	...	..	...	..	...	..	...
Carry-over control 3 years following application; DeKalb field only												
Northern corn rootworm	2	63	2	92	..	...	..	...	..	...	..	...

heptachlor, and dieldrin at the above rates gave good control of cutworms. In one test, aldrin and heptachlor at 1½ pounds an acre apparently gave good control of seed-corn beetles.

All the insecticides appeared to give good to excellent control of northern corn rootworms. In one experiment on the DeKalb field, heptachlor appeared to kill a minimum of 92 percent of northern corn rootworms for at least 4 years (Table 3). For the same period, aldrin gave a minimum of 63-percent mortality. It was somewhat less thoroughly applied than heptachlor, and under the same conditions might have been equally effective in control of northern corn rootworm.

The test on Japanese beetle control (Table 4) showed that 2 pounds of dieldrin to the acre in granular form applied by airplane in April before the soil was plowed killed 100 percent of the full grown overwintering larvae. Aldrin and heptachlor at 1½ pounds to the acre sprayed broadcast and disked in the first of June did not effectively control the full-grown larvae. Both insecticides, however, gave excellent control of newly hatched larvae. It appears that general recommendations for control of soil insects will control Japanese beetle as well as other white grubs. Observations also indicated that cultural practices, as well as natural factors, greatly reduced the Japanese beetle populations in corn and soybean fields.

Cooperative tests

Much better information concerning control of soil insects with two insecticides, aldrin and heptachlor, was obtained from farmers' fields than from the experimental plots, largely because there were more observations in farmers' fields and the chances for suitable insect infestations were greater. Also farmers used a number of different methods of application and a number of different rates. These variables gave some data on the effects of those factors on control. (For information concerning control of eight insects or groups of insects with aldrin and heptachlor at recommended or less-than-recommended rates, see Table 5.) Minimum recommended rates, based on data obtained in 1953, were 1½ pounds per acre of active ingredient applied broadcast, or 1 pound per acre applied in the row.

It was recognized that variations were bound to occur. Therefore, under recommended dosages in Table 5 were included instances in which farmers applied at least 1.3 pounds of the insecticides broadcast or 0.8 pound in the row. (For data on the several methods of application farmers used, see Table 6.) Only recommended dosages were included in Table 6. The results and recommendations and certain authentic observations by farmers given in the following paragraphs are taken from these tables, 5 and 6.

Table 4.—NATURAL, CULTURAL, AND INSECTICIDAL CONTROL OF JAPANESE BEETLE: Cornfield and Soybean Field; 1957 Averages

Treatment	Date	Cornfield, number of beetles[a]			Soybean field, number of beetles[a]		
		Untreated area	Treated area	Apparent mortality, percent	Untreated area	Treated area	Apparent mortality, percent
Overwintering brood							
None	April 16	135.0	...	...	183	...	...
Plowing, disking, and planting	June 21	135.0	6.5	95	183	10	95
Plowing, disking, planting, and cultivating	July 11	135.0	6.0	96	...	...	...
Dieldrin at 2 pounds per acre applied by airplane	June 21	6.5	0	100	...	...	...
Aldrin as broadcast spray applied at 1½ pounds per acre	June 21	6.5	5.5	15	4	5	0
Heptachlor as broadcast spray at 1½ pounds per acre	June 21	6.5	5.0	23	4	2	50
Summer brood							
Dieldrin granules at 2 pounds per acre applied by airplane	August 6	63.0	0	100	...	...	...
Aldrin as broadcast spray applied at 1½ pounds per acre	August 6	63.0	38.0	40[b]	...	...	...
Aldrin as broadcast spray applied at 1½ pounds per acre	August 16	23.0	8.0	65[b]	25	13	48[b]
Aldrin as broadcast spray applied at 1½ pounds per acre	September 3	15.0	2.0	87[c, d]	7	0	100[d]
Heptachlor as broadcast spray applied at 1½ pounds per acre	August 6	63.0	18.0	71[b]	...	...	...
Heptachlor as broadcast spray applied at 1½ pounds per acre	August 16	23.0	5.0	78[b]	25	5	80[b]
Heptachlor as broadcast spray applied at 1½ pounds per acre	September 3	15.0	0	100[d]	7	0	100[d]

[a] All forms at various stages of development.
[b] Eggs and larvae.
[c] Eggs only.
[d] Included both natural and insecticidal control. Note 76 percent apparent natural reduction even while oviposition was in progress.

Table 5.—CONTROL WITH ALDRIN AND HEPTACHLOR AT RECOMMENDED AND LESS THAN RECOMMENDED DOSAGES: Cooperators' Fields, 1954-1957

Insects	Recommended dosages				Less than recommended dosages			
	Aldrin		Heptachlor		Aldrin		Heptachlor	
	Number of tests	Percent control	Number of tests	Percent control	Number of tests	Percent control	Number of tests	Percent control
	Results in year applied							
Wireworms	21	81	8	86[a]	2	64	0	..
White grubs[b]	7	94	4	73[c]	4	67	4	91
Northern corn rootworms	10	94	4	91	1	83	0	..
Southern corn rootworms	2	97	2	100	0	..	0	..
Cornfield ants	20	65[d]	4	90	7	63	1	50
Corn root aphids	7	70	2	83	3	61	0	..
Cutworms	2	71	2	78	0	..	0	..
Seed-corn beetles	1	100	1	100	1	0	0	..
	Carry-over control year following application							
White grubs[b]	0	..	0	..	1	100	0	..
Northern corn rootworms	5	82	0	..	1	96	0	..
Southern corn rootworms	1	100	1	100	0	..	0	..
Cornfield ants	0	..	0	..	4	44	0	..
Corn root aphids	0	..	0	..	4	47	0	..
Cutworms	3[e]	..	0	..	..	..	0	..
Seed-corn beetles	..	..	..	..	1	0	..	..

[a] Includes one field where trash was very abundant and humus in soil very high; no control of *Conoderus* species.
[b] Largely *Phyllophaga* and *Cyclocephala.*
[c] Heptachlor plots apparently contained a larger number of full grown larvae than aldrin plots.
[d] Materials applied in bands ineffective. This was the reason for poor control.
[e] Farmers' records.

Table 6.—EFFECT OF METHOD OF APPLICATION: Recommended Rates; Aldrin and Heptachlor; Cooperators' Fields, 1954-1957

Insect	Method of application									
	Sprayed broadcast		Granules in rows		Liquid over rows		In dry fertilizer (in row)		In dry fertilizer broadcast	
	Number of tests	Percent control	Number of tests	Percent control	Number of tests	Percent control	Number of tests	Percent control	Number of tests	Percent control
Wireworms	22	88	2	60	2	90	1	50	1	67[a]
White grubs[b]	9	85	3	99	1	100	1	89	0	..
Northern corn rootworms[c]	11	93	0	..	0	..	0	..	1	100
Southern corn rootworms	2	100	0	..	0	..	9	..	1	95
Cornfield ants	8	79[d]	2	16	4	39	2	40	0	..
Corn root aphids	4	83[e]	3	55	2	58	0	..	0	..
Seed-corn beetles	4	87	0	..	0	..	0	..	0	..
Cutworms	4	75	0	..	0	([f])	0	..	0	..

[a] Applied in late fall or early spring.
[b] *Phyllophaga* and *Cyclocephala*.
[c] One pound per acre sprayed broadcast considered recommended rate.
[d] Included 2 fields with no control with aldrin at 1½ and 2 pounds per acre. For some unexplained reason, aldrin gave poor control on occasion.
[e] Included 1 field with poor control of ants and aphids at a rate of 2 pounds of aldrin per acre.
[f] Reported excellent by several farmers.

Wireworms. In general, aldrin and heptachlor were about equally effective although in 1957 some near failures occurred with aldrin. Dosages of 1½ pounds per acre sprayed broadcast and disked in, or 1 pound in liquid sprayed in bands over the row gave the best control. Insecticides in granules or in dry fertilizer applied at planting time or in dry fertilizer applied in the late fall or early spring were less effective. Large, full-grown wireworms 2 or 3 years old were very difficult to kill. Dosages well above those recommended for general use — dosages up to 3 pounds per acre — would be required to control them. Fortunately, wireworm infestations seldom comprise only full grown larvae.

White grubs. Aldrin in general gave somewhat better control than heptachlor. Applications of 1½ pounds to the acre broadcast or 1 pound in the row are satisfactory except where large 2- and 3-year old grubs occur. Then 3 pounds to the acre are necessary. This is especially true where corn is grown in a corn-soybean rotation. The rotation allows the May beetle, *Phyllophaga rugosa,* to lay its eggs in the soybeans and to become very abundant at times. Experience has shown that where the grower is dealing with a heavy infestation of these large grubs, the insecticides should be applied at least 2 weeks before the corn is planted. Otherwise the big grubs can destroy large numbers of the young corn plants before the insecticides become fully effective. The method used to apply the insecticides had no apparent effect on control.

Northern and southern rootworms. Aldrin and heptachlor at 1 pound per acre broadcast as sprays or broadcast in fertilizers were equally effective. Applying insecticides in the rows was not tested. These insects appear to be easy to control with insecticides. Even smaller dosages than those recommended gave good control for at least 2 years — as long as observations in these particular fields ran. As was shown earlier — Table 3 — experimental tests gave good apparent control of northern corn rootworm for as long as 4 years when heptachlor was applied as a broadcast spray at the rate of 1½ pounds to the acre.

Cornfield ants and corn root aphids. These insects were controlled when 1½ pounds of aldrin or heptachlor were applied as broadcast sprays. The insecticides were not effective when applied in the rows. It appears that the ants were able to detect the insecticide and when it was placed in the rows, avoid it, but, of course, they could not avoid it when it was broadcast. Numbers of ant colonies with accompanying aphids were found between the rows in fields where row applications of insecticides were made. In one year, after 1 pound of aldrin was sprayed broadcast, ant and aphid colonies were apparently reduced only 44 and 47 percent respectively. No records of carry-over control with heptachlor or aldrin at dosages of over 1 pound per acre were obtained.

Cutworms. Aldrin and heptachlor at 1½ pounds per acre sprayed broadcast and disked in gave fair to good control in the cooperative tests and in one experimental plot. Farmers' reliable observations have shown that 1 pound of aldrin sprayed in a band over the row at planting time gave excellent control. Fields treated in 1956 with 1½ pounds of aldrin per acre were observed to be severely damaged by cutworms in 1957, indicating little or no carry-over control from one year to the next.

Corn billbugs. Both aldrin and heptachlor have been used to control corn billbugs, which often cause losses in bottomland or in other areas where nutgrass grows in or around the fields. The minimum dosage necessary for good control was not determined, but dosages of aldrin or heptachlor at 2 pounds per acre have given good control in some other areas. Tests in Illinois and elsewhere indicate that the billbugs migrating into a cornfield from the outside are not killed the year following treatment. When ditches, field borders, or grass waterways in or near a field to be planted to corn have heavy growths of nutgrass, they should be treated with aldrin or heptachlor if the field has a history of billbug damage.

Effects on other soil insects. Both aldrin and heptachlor destroyed most of the ground beetle larvae, which are predators of soil insects. However, none of the insecticides tested in either farmers' fields or experimental plots adversely affected the earthworm populations. In fact, the earthworm populations in areas treated with insecticides appeared to be somewhat larger than those in untreated areas.

Effects on Plant Populations

Experimental tests

Counts of plant populations were made on all experiment fields to determine the over-all effect of the soil treatments. Results on the fields in Champaign county showed there were more plants on the treated than on the untreated areas (Table 7). Data show that differences in favor of treatment were significant at the 1-percent level for aldrin, dieldrin, and heptachlor, the insecticides included in all 16 tests. In 11 tests, including all insecticides except chlordane, differences in favor of treatment were significant at the 1-percent level for aldrin and heptachlor, and at the 5-percent level for dieldrin and endrin. In 6 tests where all insecticides were used, differences in favor

Table 7.—EFFECT OF TREATMENT ON PLANT POPULATIONS: 16 Tests; Experiment Fields; Champaign County, 1954-1957

Insecticide and number of tests	Increases resulting from treatment	
	Number of plants per acre	Percent
Sixteen tests		
Aldrin	786**	6.7
Dieldrin	521**	4.2
Heptachlor	642**	5.2
Eleven tests		
Aldrin	891**	7.3
Dieldrin	686*	5.6
Heptachlor	739**	6.0
Endrin	445*	3.6
Lindane	403	3.3
Six tests		
Aldrin	671**	5.2
Dieldrin	571**	4.4
Heptachlor	461*	3.6
Chlordane	113	0.9
Endrin	396	3.1
Lindane	296	2.3

Note: two asterisks indicates a significant difference at the 1-percent level; one asterisk indicates a significant difference at the 5-percent level.

of treatment were significant at the 1-percent level for aldrin and dieldrin and the 5-percent level for heptachlor. Plant populations on plots treated with either lindane or chlordane were not significantly higher than populations on the untreated plots of the field.

On the experimental field at DeKalb when aldrin was used, plant counts indicated a declining residual effect 1 and 2 years after a single treatment (Table 8). This was not true on the plots treated with hep-

Table 8.—EFFECT OF TREATMENT WITH ALDRIN AND HEPTACHLOR ON PLANT POPULATIONS: Experiment Field, DeKalb; 1954-1956

Year data recorded	Years treated	Increases resulting from treatment			
		Aldrin		Heptachlor	
		Number of plants per acre	Percent	Number of plants per acre	Percent
1954	1954	1,258	8.4	524	3.5
1955	1954	734	5.6	472	3.6
1955	1954-1955	2,646	20.1	917	7.0
1956	1954	524	3.7	917	6.4
1956	1954-1955	1,572	11.0	917	6.4
1956	1954-1955-1956	393	2.8	891	6.3

tachlor and may indicate heptachlor has a longer residual life. Heptachlor tends to remain in its original form over a longer period than aldrin.[4] The relatively small differences in 1956 in the aldrin plots treated 3 successive years may possibly be due to planter trouble. Otherwise, they are inexplicable.

Cooperative tests

During 1953-1957, cooperators made 352 tests with aldrin or heptachlor applied on fields being treated for the first time in a rotation. These tests were on fields in which the seed in neither the treated nor untreated portions of the field had been treated with an insecticide. These treatments included applications broadcast as sprays or granules and disked in, and row treatments either as sprays or granules applied with special attachments on the planter or applied as insecticide-fertilizer mixtures. They also included varying amounts of insecticide, depending on the accuracy with which the farmer calibrated his equipment. Over 310,000 plants were counted on these plots. The treated areas contained an average of 9,643 more plants than the untreated areas (Table 9). This is an average of 718 or 6.3 percent more plants per acre per field.

In 1954 and 1955, careful counting and weighing of representative areas showed that an increase of 350 plants per acre on the treated areas paid for the insecticide and application. Sixty-seven percent of all treated fields showed that much increase.

Comparison of insecticides, Cooperators' fields

No heptachlor was used in 1953. In each succeeding year, however, both heptachlor and aldrin were used and results with each compared

Table 9.—EFFECT OF TREATMENT WITH ALDRIN AND HEPTACHLOR ON PLANT POPULATIONS: All Treated and Untreated Areas; First Year of Treatment; 352 Cooperators' Fields; 1953-1957

Year	Number of tests	Total number of plants		Increases resulting from treatment		
		Treated areas	Untreated areas	Number of plants	Plants per acre	Percent
1953	37	16,361	14,916	1,445	1,024	9.7
1954	103	44,663	41,655	3,008	765	7.2
1955	93	43,503	41,429	2,074	584	5.0
1956	64	29,795	27,904	1,891	773	6.8
1957	55	28,728	27,503	1,225	582	4.4
1953-1957	352	163,050	153,407	9,643	718[a]	6.3

[a] Differences resulting from treatment were significant at the 1-percent level.

Table 10.—EFFECT OF ALDRIN AND HEPTACHLOR ON PLANT POPULATIONS: 34 Tests; Cooperators' Fields; First Year of Treatment; 1954-1957

Year	Number of tests	Total number of plants			Increases resulting from treatment			
					Aldrin treated areas		Heptachlor treated areas	
		Untreated areas	Aldrin treated areas	Heptachlor treated areas	Number of plants per acre	Percent increase	Number of plants per acre	Percent increase
1954.......	2	710	772	742	810	8.7	419	4.5
1955.......	8	3,813	4,203	3,978	1,279	10.2	542	4.3
1956.......	14	5,972	6,575	6,501	1,127	10.1	990	8.9
1957.......	10	4,624	4,786	4,971	424	3.5	909	7.5
1954-1957	34	15,119	16,336	16,192	938[a]	8.1	825[a]	7.1

[a] Difference between aldrin and heptachlor not significant. Each treatment was significantly better than untreated areas at the 1-percent level.

to a common untreated area. During the 4-year period, 34 such tests were conducted involving counts of over 45,000 plants. The plots treated with aldrin contained an average of 938 or 8.1 percent more plants than the untreated plots (Table 10). The plots treated with heptachlor contained an average of 825 or 7.1 percent more plants than the untreated plots. Statistical analysis showed no significant difference between treatment with aldrin and heptachlor, but as against the untreated plots, each was significantly better. Neither was consistently superior to the other, the order of apparent effectiveness changing from field to field.

Broadcast treatment compared with row treatment, Cooperators' fields

During 1954-1957, a total of 239 tests was checked. These were tests in which some factor other than method of application did not confuse the results. They included 180 tests in which insecticides as sprays or granules were broadcast and 59 in which they were applied in the row. They included insecticide-fertilizer mixtures. They exclude fields on which less than recommended amounts of insecticides were used. About 218,000 plants were counted in these fields. The broadcast treated areas contained 789 or 6.8 percent and the row-treated areas 542 or 4.6 percent more plants than the untreated areas (Table 11). Thus broadcast treatment gave significantly better results than row treatment, but the results with row treatment when recommended amounts of insecticide were used were still profitable. The best results

Table 11.—EFFECTIVENESS OF BROADCAST APPLICATIONS COMPARED WITH ROW APPLICATIONS: Recommended Amounts of Insecticide; First Year of Treatment; 239 Tests; Cooperators' Fields; 1954-1957

Year	Number of tests	Total number of plants		Increases resulting from treatment	
		Untreated areas	Treated areas	Plants per acre	Percent increase
Broadcast-treated areas					
1954	56	21,749	23,457	799	7.9
1955	39	18,119	19,158	697	5.7
1956	38	16,099	17,681	1,090	9.8
1957	47	23,527	24,608	613	4.7
1954-1957	180	79,494	84,904	789[a]	6.8
Row-treated areas					
1954	18	7,942	8,351	595	5.1
1955	22	9,665	10,151	579	5.0
1956	12	5,428	5,600	377	3.2
1957	7	3,277	3,435	592	4.8
1954-1957	59	26,312	27,537	542[a]	4.6

[a] Difference between methods significant at 1-percent level.

with row treatments were obtained when insecticides were placed over the row. (Note: this test was also conducted in 1953, but data for it were not included in Table 11 because many of the results of row treatment were confused by the use of seed treatment also.)

Amounts of insecticide used

Following the 1953 season, the use of 1½ pounds of active ingredient per acre was recommended for use broadcast and 1 pound for use in the row. The results with recommended and less than recommended amounts of insecticides were compared. The tests included broadcast and row treatments and sprays or granules of both insecticides. In the 288 tests in which the results of using recommended and less than recommended amounts could be studied, 236 were made with recommended and 52 with less than recommended amounts of insecticides (Table 12). In the tests using recommended amounts, there was an average of 736 or 6.3 percent more plants per acre on the treated areas than on the untreated. When less than the recommended amounts were used, there was an average of 519 or 4.6 percent more plants per acre on the treated than on the untreated areas. The difference is significant at the 1-percent level.

Many of the unsatisfactory results obtained with row treatments in 1956 and 1957 were in fields on which insecticide-fertilizer mixtures were used. During 1954 and 1955, in several of the fields on which

Table 12.—EFFECTIVENESS OF TREATMENT WITH RECOMMENDED COMPARED WITH LESS THAN RECOMMENDED AMOUNTS OF INSECTICIDE: 288 Tests; 1954-1957

Year	Treated with at least recommended amounts[a]			Treated with less than recommended amounts		
	Number of tests	Increases resulting: Plants per acre	Increases resulting: Percent	Number of tests	Increases resulting: Plants per acre	Increases resulting: Percent
1954	76	747	6.9	21	752	7.4
1955	59	652	5.5	14	511	4.6
1956	50	935	8.3	14	257	2.2
1957	51	624	4.8	3	157	1.1
1954-1957	236	736[b]	6.3	52	519[b]	4.6

[a] Considered recommended amount if 1.3 pounds or more was applied broadcast or 0.8 pound or more was applied in the row.
[b] The difference between these two figures is significant at the 1-percent level.

less than recommended amounts of insecticide were used, rootworm, which is easier to control than some insects, was the only insect problem. Practically all the data for these two years came from fields where insecticides were applied broadcast.

Effect of position in the rotation

During 1954-1957, information from cooperators allowed the study of the possible effect of previous crops on the effectiveness of soil treatments on 289 fields. These fields included all methods of application and all amounts of insecticides. The figures indicated that for the 4 years treatments were economical in all cases (Table 13). The economy effected, however, varied from year to year and field to field, depending on the prevalence of one or more insects in any field in any one year and can be expected to vary in the future. The greatest advantage of treatment appeared to be in second-year corn and the least following alfalfa or an alfalfa-grass mixture. The 4-year averages, however, were not significantly different. On the basis of this information, no prediction can be made concerning the fields on which treatment is likely to be most profitable.

Effect of treatment in two successive years

During these studies, there was opportunity to examine 26 fields where soil treatment was applied for the second year in succession. All were fields where recommended amounts of insecticide were broadcast. They were on land where the entire field had been treated the first year and a portion of this area left untreated the second year.

Table 13. — EFFECT OF PREVIOUS CROPS ON SOIL TREATMENTS: Increases in Number and Percent of Plants in Treated Areas; 289 Cooperators' Fields; 1954-1957

Crop the previous year	Number of tests	1954		1955		1956		1957		1954-1957[d]	
		Number of plants per acre	Percent increase	Number of plants per acre	Percent increase	Number of plants per acre	Percent increase	Number of plants per acre	Percent increase	Number of plants per acre	Percent increase
Alfalfa[a]	36	812	7.7	364	3.0	493	4.3	511	3.7	519	4.2
Clover[b]	45	870	8.4	880	8.0	413	2.8	595	4.6	713	6.5
Small grain	37	537	4.6	561	4.6	755	7.5	927	8.3	626	5.4
Soybeans	39	490	4.7	566	5.1	1,323	11.6	629	5.0	679	6.1
Grass	23	707	5.5	165	1.4	768	6.1	...	...	595[c]	4.9
Corn, first year	180	673	6.1	555	4.7	702	6.1	621	4.8	642	5.5
Corn, second year	66	1,090	10.9	440	4.1	1,011	8.8	676	5.2	859	7.7
Corn, three years or more	43	723	7.0	833	6.7	1,389	13.5	236	1.4	760	6.4

[a] Includes alfalfa-grass mixtures and catch crops.
[b] Includes red- and sweet-clover-grass mixtures and catch crops.
[c] No data in 1957. Records for three years only.
[d] Averages are not significantly different.

The figures for this test are given below.

Year	Number of tests	Increases resulting from treatment for 2 years in succession: Number of plants per acre	Percent
1954	2	1,205	13.4
1955	4	262	2.3
1956	16	432	3.5
1957	4	935	9.6
1954-1957	26	545[a]	5.1

[a] Difference significant at the 1-percent level.

These data show that there was an average of 545, or 5.1 percent, more plants on the areas treated the second successive year than on the area treated only the first year. This difference is significant at the 1-percent level. Although these data do not appear to conform to insect control records for the year following treatment, they show control of insects not included in the insect control records (Table 3) and may be largely a result of control of cutworms, seed-corn maggots, and seed-corn beetles.

Seed treatment tests

During the course of the testing program, there was opportunity to test seed treatment applied by the farmer as compared to soil treatment. In most cases in 1953 and 1954 the insecticide was lindane and the following years dieldrin. In all cases recorded (Table 14), the insecticide was applied to the seed in the planter box at the rate recommended by the manufacturer. In 43 tests, all the seed used in a field was treated and a portion of the field also received soil treatment. These tests showed an average of 742, or 7 percent, more plants per acre when soil treatment was superimposed on seed treatment than when it was not.

In other cases, a portion of the field was planted with treated seed, a portion was given soil treatment, and a portion was given no treatment. In 15 such tests, the area planted with treated seed contained 765 fewer plants per acre than the untreated area, a decrease of 6 percent. But the portion of the field given soil treatment contained an average of 857 more plants per acre than the untreated area, an increase of 6.8 percent.

Effect of treatment on yield

During the period of the tests, yield data were secured on 55 plots where hand-picked samples were taken. Increased yields for treatment ranged from 0 to 21.4 percent and averaged 6.8 percent. The greatest

Table 14. — EFFECT OF SEED TREATMENT ADDED TO PLANTER BOXES AND SOIL TREATMENT WITH AND WITHOUT SEED TREATMENT: 58 Tests; 1953-1957

	1953	1954	1955	1956-1957[a]	1953-1957
Soil treatment superimposed on seed treatment					
Number of tests..........	20	7	16	......	43
Increased number of plants on soil-treated over seed-treated areas					
Number of plants per acre..............	922	736	514	......	742
Percent...............	9.6	6.9	4.4	......	7.0
Seed treatment compared with soil treatment, same fields					
Number of tests..........	......	7	6	2	15
Difference between number of plants on treated and untreated areas					
Seed treated					
Number of plants per acre............	......	−1,454	162	−1,140	−765
Percent............	......	−11.2	1.3	−9.7	−6.0
Soil treated					
Number of plants per acre............	867	1,009	354	......	857
Percent............	6.7	8.0	3.0	......	6.8

[a] Combined because of small number.

increases occurred in fields known to have relatively severe infestations of wireworms, grubs, and cutworms. Some failures to show increased yields from treatment occurred where drouth had reduced soil moisture to such an extent that the larger plant populations in treated areas actually caused the entire plant population to suffer. The insecticides used and the rate of use in these tests did not affect the corn plant directly, but indirectly affected it by controlling the insects feeding on it.

SUMMARY

Cornfields in Illinois, as this 5-year study shows, may be damaged by one or more of these underground insects: wireworms, white grubs, grape colaspis, cornfield ants, corn root aphids, or rootworms. They were present in significant numbers in 38 percent of the fields studied and may do considerable economic damage. The extent of infestation was determined by digging in untreated portions of cornfields throughout the state. Abundance of the insects mentioned above appears to be most likely when corn is grown more than two years in succession in a field or when corn follows a legume-grass mixture.

Cornfields are also damaged by seed-corn maggots, seed-corn beetles, cutworms, billbugs, and possibly other insects. Plant population counts suggest that such damage may occur in an added 30 percent of the fields. Over-all damage by these insects was measured by counts of plant populations in treated and untreated parts of the fields.

Aldrin and heptachlor at a rate of 1½ pounds of active ingredient to the acre and dieldrin at 1 pound to the acre, all sprayed broadcast and disked in ahead of planting, gave good to excellent control of all insects under study. They also provided the largest increases in plant populations in the treated portions of the fields. Aldrin and heptachlor at 1 pound per acre, broadcast and disked in, gave very good control of corn rootworms. These insecticides at 1 pound per acre applied over the row and covered with soil controlled most, but not all, the insects studied. Insecticide-fertilizer mixtures used at planting time and placed in the row were not always effective, especially if less than 1 pound of insecticide per acre was used.

Insecticides at rates recommended are not detrimental to the plants. They destroy some predators but do not reduce the earthworm population.

LITERATURE CITED

1. DAVIS, J. J. Common white grubs. U. S. Dept. Agr., Farmers Bul. 940. 1926.
2. FORBES, S. A. Experiments with repellents against the corn root aphis, 1905 and 1906. Ill. Agr. Exp. Sta. Bul. 130. 1908.
3. FORBES, S. A. Recent Illinois work on the corn root aphis and the control of its injuries. Ill. Agr. Sta. Bul. 178. 1915.
4. GANNON, N., and BIGGER, J. H. The conversion of aldrin and heptachlor to their epoxicides in soils. Jour. Econ. Ent. **51** (1): 1-2. 1958.
5. GRAYSON, J. M., and POOS, F. W. Southern corn rootworm as a pest of peanuts. Jour. Econ. Ent. **40** (2): 251-256. 1947.
6. GREENWOOD, D. E. Wireworm on potatoes. Conn. Agr. Exp. Sta. Bul. 512. 1946.
7. HINDS, W. E. Carbon disulphid as an insecticide. U. S. Dept. Agr., Farmers Bul. 799. 1917.
8. NEWELL, W. Measures suggested against the Argentine ant as a household pest. Jour. Econ. Ent. **2** (5): 324-332. 1909.
9. SMITH, J. B. The cabbage and onion maggots. N. J. Agr. Exp. Sta. Bul. 200. 1907.

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