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FIELD EXPERIMENTS AND OBSERVATIONS ON INSECTS INJURIOUS TO INDIAN CORN

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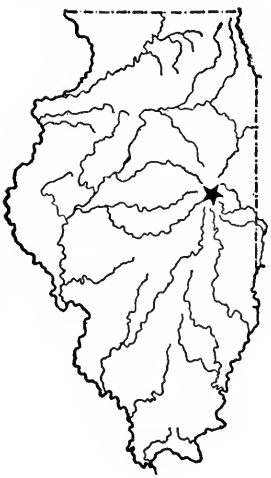

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Contents of Bulletin No. 104.

INJURY TO CORN BY THE TIMOTHY BILL-BUGS (*SPHENOPHORUS* SP.).

In a general article on "The Corn Bill-bugs in Illinois," published in my Eleventh Report as State Entomologist (pages 1-26), a brief account was given of observations made in fields near Taylorville, Christian county, in 1902 (page 7); but the data in my possession concerning injuries to corn at this place and their relation to previous crops and to the history of the land, were not fully utilized in that paper. Our observations and correspondence have made it evident for some time that bill-bug injury to corn is imperfectly appreciated by corn growers and but little understood by them, and it consequently seems desirable that the careful work done on this insect injury near Taylorville should now be fully reported and thoroughly discussed.

June 26, 1902, Mr. D. S. Dalbey, a senior agricultural student in the University of Illinois, sent me the following note:—

"I have received from my father, Wm. M. Dalbey, of Taylorville, Illinois, some specimens of corn plants affected by the corn bill-bug. The land on which the infested corn was grown is timothy sod plowed in April of this year, and is located two miles northeast of Taylorville, on my father's farm. The damaged area covers forty acres, and the extent of the damage involves about half the stand. The plants affected are not dead, but have a sickly yellow color, and the leaves are punctured with holes."

I further learned that this land had been in timothy for the four years preceding, and the year before that in wheat. Clover and timothy had been originally sown together, but the clover ran out and the crop was practically pure timothy by 1901.

Examination of Injured Field.

June 30, 1902, I sent Mr. E. S. G. Titus to Taylorville with instructions to make a careful study of the condition of the infested field and to collect information for a comparison of its agricultural history with that of other fields of corn in its neighborhood, the object being to ascertain the full effect of bill-bug injury to corn on uplands, and to discover any differences in respect to this injury due to differences of agricultural management.

This work was done by Mr. Titus with characteristic thoroughness, intelligence, and skill. On his first visit, made June 30, he platted the Dalbey field, selecting and marking 650 hills which had been more or less injured by corn bill-bugs. On another visit, August 10 and 11, he made notes on the condition of these hills, and

October 2 and 3 he carefully examined them with reference to the condition of the stalks and the number and quality of the ears, in comparison with like facts concerning uninjured hills in the same field. Observations were also made on the condition of fields of corn on other farms of the neighborhood. The data thus obtained have since been summarized and tabulated for comparative study, and the materials are thus in hand for a fuller study of *Sphenophorus* injury to this crop than has ever before been reported.

DISTRIBUTION OF INJURY.

The injury to the corn in the Dalbey field was very uneven. In one corner almost every stalk on several acres had been damaged, while in other parts from 25 to 50 per cent. of the plants had been attacked. The distribution of the injury seemed not affected by the lay of the land or the moisture in the soil, there being more injury on low moist ground at one side of the field and less on similar ground at the other side than there was on the higher and drier ground.

THE INJURIOUS SPECIES.

The species of *Sphenophorus* actually responsible for this mischief was not definitely ascertained, the beetles having all disappeared from the field; but as the larva of *Sphenophorus parvulus* was common in the bulbous roots of timothy on adjacent premises, and as the old timothy bulbs still present in the injured corn field had been similarly hollowed out by bill-bug larvæ the year before, the probability is strong that this species was largely concerned in the injury under observation.

THE INJURY TO TIMOTHY.

Fields of timothy near by, which had been in that crop for three or four years in succession, had at this time from 50 to 75 per cent. of the bulbs more or less injured and infested, many of them containing larvæ ranging in size from those evidently but just hatched to those large enough to fill the whole timothy bulb. In fields but two years in timothy, on the other hand, from 10 to 20 per cent. of the bulbs were infested. The injured plants were inclined to throw out suckers at the base and also at the first joint above the ground. Where the bill-bug larva had eaten out all the substance of the bulb, it had often drilled into an adjacent bulb, and was found feeding therein. Some larvæ were seen just cutting their way out of the first bulb, and others in the act of boring into the second, a part of

the body in each. The effect of this amount of infestation on the timothy crop itself must certainly have been considerable, and the conditions were, of course, unusually dangerous to the corn crop following.

THE INJURY TO CORN.

The injury to corn had resulted variously, the differences being probably due to the age of the plant when injured, and to the number of punctures made in a single stalk. In many cases, as will be presently shown, the stalk had been killed, doubtless when the plant was still quite young. In other cases the stalk, though nearly or quite full grown, had fallen to the ground in consequence of a deficient root development, brace-roots being indeed practically lacking. Injured stalks were also smaller than normal just above the ground and at the joints higher up, and were likely to lean from the base or to bend at the weakened joints. A considerable percentage of the stalks in hills which had been infested had never formed the ear (at least 33 per cent. of these stalks being barren, as against 4 per cent. in uninfested hills), and on a much larger percentage of them the ear was either a small nubbin or imperfectly filled out. It was the owner's opinion that the worst-infested parts of the field averaged about twenty bushels of corn to the acre, and that the part not infested yielded from forty-five to fifty-five bushels.*

*A letter received from Mr. H. L. Jones, of Geneva, Ill., since this manuscript was prepared, makes mention of an effect of bill-bug infestation which has not previously been noticed, and describes also his method of diminishing the damage. He says: "I had a rather expensive experience with bill-bugs last season on a pasture plowed in spring. They appeared when the corn was four to six inches high, and crippled it badly in spots so that the injured inner leaf would break over and curl up, thereby preventing the next inner leaf from coming out and thus dwarfing the stalk. I immediately put men and boys into the field, who replanted the destroyed hills and picked the curled tops from all the damaged stalks, in this way saving nearly all the crop. This corn husked seventy bushels per acre where I am sure that it would have yielded eighty bushels but for the damage sustained. If the curled leaves had not been picked from the tops of the plants, I think that the crop would not have been more than fifty bushels. The labor cost about $5.00 for twelve acres, and it might help some other man to know my experience in saving part of a crop."

GENERAL RESULTS OF THE INJURY.

As affecting the whole Plant.—For a precise comparison of the condition of uninjured corn with that of corn attacked by the bill-bugs, 328 hills were carefully selected as representing the average condition of infested and uninfested hills in this field. One hundred and sixty-four of these were free from injury, and each of the remaining 164 contained injured stalks. There were, in all, 363 *stalks* in the uninjured hills and 313 in the injured hills,—a difference indicating that 50 stalks, or 14 per cent. of the whole, had been killed by the bill-bugs. In the uninjured hills 306 stalks were standing erect, 29 were leaning, and 28 had fallen to the ground. In the injured hills 64 stalks were standing, 99 were leaning, and 150 had

fallen. That is, 33 per cent. of the number of the stalks which should have been erect in the injured hills had been made to fall, and 19 per cent. of them had been weakened sufficiently to cause them to lean or bend. More generally speaking, 67 per cent. of the stalks—that is, 242 out of 363—had been either killed or noticeably injured in the infested hills.

The ratio of damage to the plant as a whole may be more simply and forcibly shown by saying that in the uninjured hills there were 306 stalks erect and in good condition, while in the injured hills there were but 64 such stalks. In other words, the bill-bugs had killed or palpably damaged 79 per cent. of the stalks in the infested hills which would have continued in good condition except for this insect attack.

As affecting the Ears.—Comparing the two lots with reference to the number and condition of the *ears* borne by them respectively, we find that the uninjured hills bore 349 ears of all kinds, and the injured hills 211,—a loss of 138 ears, or 40 per cent. of the whole. Of the uninjured corn 282 of the ears were graded as good, 44 as fair, 14 as poor, and 9 as nubbins, while the injured corn bore 24 good ears, 75 fair ears, 72 poor ones, and 40 nubbins.* (See Fig. 1.) Otherwise stated, besides the 40 per cent. of the ears which had been sacrificed to the bill-bugs, 9 per cent. had been considerably injured and 26 per cent. had been badly injured as a result of bill-bug attack. Not less than 75 per cent. of the ears in these hills were thus either lost or seriously injured.

The loss in number and condition of the ears borne by infested hills may perhaps be more clearly illustrated by the statement that 282 good ears were borne by the uninjured hills and only 24 by the injured,—a loss and injury combined amounting to 81 per cent.

It further appears from the data in hand that the uninjured hills bore 96 ears per hundred stalks, and the injured hills 67 ears per hundred,—a loss of thirty per cent. in number of ears per hundred stalks,—and that the uninjured corn yielded an average of 200 good or fair ears per hundred hills, and the injured corn 73 such ears per hundred hills,—a loss of 61 per cent. in number of fairly good ears.

Total Amount of Injury.

The above ratios do not hold, of course, for the entire field, but only for the part injured, and for an understanding of the condition of the field in general an estimate of the percentage of injured hills is necessary. Six hundred and eighty-two hills were examined for

*"Fair ears" were of medium size and imperfectly filled, "poor ears" were short and poorly filled, and nubbins were short, small, and not filled to the tip, and were otherwise deformed, with poor and injured grain.

this purpose, and 199, or 29 per cent., were found injured; from which we learn by a simple computation that approximately 12 per cent. of the ears which the entire field should have yielded were lost in consequence of bill-bug injury, and that 7 per cent. were badly injured and 3 per cent. considerably so.

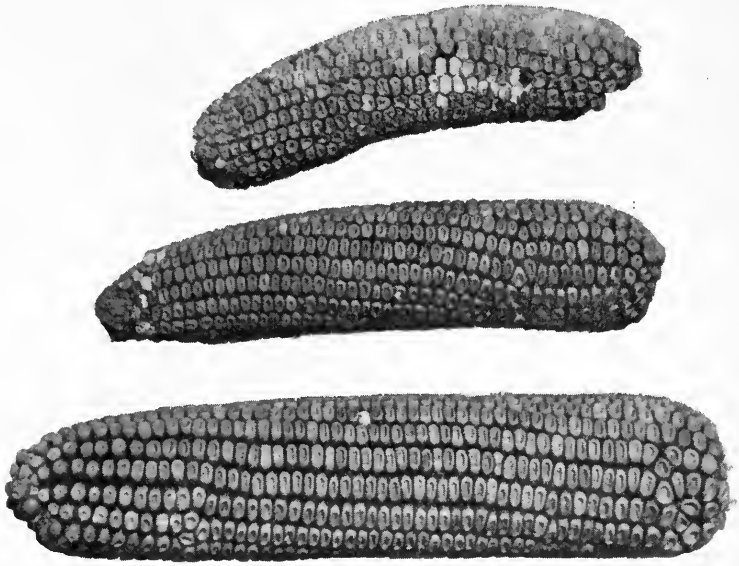

Fig. 1. Sample Ears from Dalbey field; "good," "fair," and "poor" grades of this paper.

Samples of uninjured ears and of those called badly injured, brought in by Mr. Titus, indicate that the yield from "fair ears," "poor ears," and nubbins would not be more than one third of that from an equal number of ears of the uninjured corn. It is proper to add, consequently, to the 12 per cent. of total loss some two thirds of the 10 per cent. of injured ears, making another 6 per cent. of loss, or a total of 18 per cent. for the entire field.

This conclusion is substantially supported by the owner's estimate of twenty bushels per acre for the infested area and fifty bushels for the uninfested; since, by using the above-mentioned ratio of 29 per cent. for the number of hills injured, we find that the average yield would be 41.3 bushels per acre, a quantity loss of 8.7 bushels per acre because of bill-bug injury, or 17 per cent. of the normal yield. No account is taken in this estimate of the deterioration in quality of the injured corn, which, if included, would increase the loss materially. As the season was a favorable one for corn, and as the variety used (Reid's Yellow Dent) was reported to have hardened much earlier than other varieties planted at the same time, this loss is probably under rather than over the general average un-

der similar conditions of injury. The following table will serve to exhibit these data and conclusions in more compact form.

STATISTICS OF BILL-BUG INJURY TO CORN, DALBEY FIELD, 1902.

	Uninjured hills		Injured hills		Losses from injury	
	No.	Per cent.	No.	Per cent.	No.	Per cent.
Number of hills..	164		164			
Number of stalks	363		313	86	50	14
Fallen stalks	28	8	150	48	122	33
Leaning stalks ..	29	8	99	27	70	19
Erect stalks.....	306		64	21	242	79
Number of ears..	349		211	60	138	40
Nubbins.....	9	3	40	12	31	9
Poor ears.....	14	4	72	21	58	17
Fair ears	44	13	75	22	31	9
Good ears..	282		24	9	258	81

METHODS OF PREVENTION.

The contrast observed between corn grown on timothy sod and plowed early in fall, and the Dalbey field, which was plowed only a few days before planting, was discussed in my Eleventh Report. No trace of bill-bug injury was detected on the fall-plowed land, although dead timothy bulbs still in the ground showed distinctly that they had been hollowed out by bill-bug larvæ. The inference is thus strongly suggested that early fall-plowing of timothy previous to corn planting will protect the corn from injury. A similar statement was made in 1892 by Osborn and Gossard, who say that since worse injuries are likely to occur on land in grass the preceding year or adjacent to such land, plowing should be done as early in the previous season as possible; and that since bill-bug injury is mainly done early, infested ground should be planted as late as practicable.*

John B. Smith, the State Entomologist of New Jersey, advised, in the same year, plowing of sod for corn in fall and early winter, with a view to killing out the bill-bug larvæ living in or under the sod; and in the following year he says that this injury has been minimized where fall plowing has been practiced.†

F. M. Webster also surmises ‡ that fall plowing would probably result in the diminution or prevention of the injury, and suggests planting some other crop than corn where the occurrence of this injury is very probable; and H. E. Weed says in 1895 § that where

*Bull. 18, Ia. Agr. Exper. Station, pp. 507-509.

†Twelfth and Thirteenth Ann. Reports, N. J. Agr. Exper. Station, for the years 1891 (pp. 394, 395) and 1892 (p. 390).

‡"Ohio Farmer," July 20, 1893, p. 57.

§Bull. 35, Miss. Agr. Exper. S ation, p. 154.

sod has been broken up in fall the bill-bugs will do but little damage the following spring, and that the second planting, whenever the time of plowing, will be little if at all attacked.

Early fall-plowing of grass-lands would consequently seem, in the present state of our knowledge, to diminish greatly, if not completely to prevent, injury to corn by bill-bugs the following year; a statement which must be applied to blue-grass pastures as well as to timothy meadows, since the bill-bug most abundant in timothy, *Sphenophorus parvulus,* has also been found destructive in blue-grass lawns. (See Bull. 22, U. S. Dept. Agr., Div. Ent., p. 99.)

As a check to injury to timothy meadows I see nothing better than to avoid keeping the same ground in timothy for more than two years at a time Where the pest becomes so common and destructive as in the Dalbey neighborhood, it would seem wise to substitute clover for timothy, so far as practicable, for a considerable term of years.

SUMMARY.

In a forty-acre field of corn in Christian county, injury by bill-bugs was found to have affected about 29 per cent. of the hills, diminishing the number of stalks in such hills by 14 per cent. and the number of ears by 40 per cent., and seriously injuring 26 per cent. more of the ears. It also caused about a third of the stalks in the injured hills to fall to the ground, and weakened about a fifth of them additional. The total loss in the field was estimated at 18 per cent. of the crop, or nearly nine bushels to the acre.

Comparison of this with other fields shows that the injury was due to planting corn after timothy plowed in spring, and that most of it could have been prevented by early fall-plowing of the timothy sod.

FIELD EXPERIMENTS ON THE CORN ROOT-APHIS (*APHIS MAIDIRADICIS* FORBES).

The corn root-aphis, wintering as an egg in the nests of ants in corn fields, begins to hatch, according to our observations in central Illinois, about April 8, and may continue this process for as much as six weeks, or until the latter part of May.* The earliest individuals of this first generation get their growth in approximately twenty days, and then give origin at once to representatives of the second generation, which in eighteen or nineteen days may themselves begin to reproduce. The growing period for an individual of the third generation is approximately eleven days, making a total of not far from fifty days for the entire life of a series of the first born of the first three generations from the egg. That is, by the last of May the latest to hatch of the first generation would coexist in the fields with the earliest born of the third generation. All hatching from the egg are wingless females, but a small, and no doubt variable, percentage of the second and third generations are winged, and leave their underground quarters to fly abroad and start new colonies elsewhere. The later steps of this life history are not necessary to a discussion of the experiments here reported.

In view of the fact that the young lice are dependent upon their attendant ants, at least until they have been placed upon the roots of plants suitable for their maintenance, it has seemed to me probable that an early and repeated stirring of the ground infested by these insects in early spring, scattering the eggs and young aphids again and again through the dirt, and killing the young weeds in the corn field upon which they must at first depend for food, would have the effect to destroy great numbers of them and thus to weaken the force of the aphis attack upon the young corn at a time when it is most susceptible to injury.

THE SEASON OF 1904.

With a view to testing this supposition, a field experiment was arranged in the spring of 1904, to be made in two neighborhoods notorious for some years for an abundance of the root-aphis on corn and a considerable injury to the crop in consequence. Circumstances beyond my control prevented, last year, as early a beginning as might have been desirable, and nothing was done in the experi-

*We have this year collected eggs of the corn root-aphis from ants' nests in the field May 19. These eggs hatched under our observation, and the young were maintained on corn, but were not kept until mature.

mental fields until May 13 in one locality, and May 23 in the other. I owe the opportunity to undertake the investigation at this time to Dr. J. W. Folsom, Instructor in Entomology at the University of Illinois, who was good enough to undertake the field inspections for me, and upon the report of whose observations the following statement of results is based.

The season was at least a fortnight later than usual, and it is consequently difficult to say just what generations of the aphis were in existence at the time. Judging, however, by the calendar for the three earliest generations given above, and by the field and insectary work of 1905, reported farther on, it seems likely that the first and second generations were abundant in the fields, and that the third had not yet begun to appear. That the second was present is unquestionable, since occasional winged individuals were found.

The Galesburg Cultivation Experiment. (Table I.).—In the first experiment, made on the farm of Mr. J. H. Coolidge, about three miles from Galesburg, in Knox county, Ill., two parts of a large field of corn were used, one of which (Plat A) received the usual treatment in preparation for planting and the ordinary cultivation afterwards, while in the other, the experimental plat (Plat, B), the ground was repeatedly disked and harrowed between plowing and planting, and harrowed and cultivated promptly thereafter.* In this experimental plat were thirty-two rows, each eighty rods long, and in the check plat ninety rows of the same length. The latter was plowed early in May, planted May 13 to 17, harrowed once thereafter, and cultivated June 9, the condition of the corn with reference to ants and root-lice being there determined on the 10th of June. The thirty-two experimental rows were plowed May 14 to 16, the ground was thoroughly disked three times on the 18th, 21st, and 25th of May, also harrowed May 25, and planted on this same day. It was cultivated May 28, harrowed on the 30th, and inspected June 10.

It will be noticed as an important difference between these two fields that the experimental plat was planted ten days later than the

*The various operations on the ground used in these experiments were as follows:—
First, plowing with an ordinary mold-board plow; second, harrowing with a toothed harrow; third, disking with a disk harrow; fourth, spading with a so-called spading harrow; fifth, pulverizing with a so-called "Acme" harrow, sometimes known and sold as a "pulverizer;" sixth, rolling with an ordinary smooth roller; seventh, cultivating with an ordinary "sulky" cultivator with shovels. These terms are used as above defined throughout this paper in both tables and text. The plowing in the experimental plats was from five to seven inches deep; the toothed harrow stirred the earth, as a rule, to a depth of about two inches; the disk harrow commonly worked twice as deep or more, moving the dirt laterally and mixing it thoroughly in the process; the spading harrow differed but little from the disk harrow in its operation except that it was likely to go deeper, and did not move the earth laterally to so great a distance; the "Acme" harrow, or "pulverizer," consisting of a row of blades set obliquely into an angular beam, followed by a transverse row of cylindrical pointed teeth, worked to a depth of about three inches, as a rule, stirring and pulverizing the ground more effectually than the common toothed harrow, but not to the depth of the disks or moving it laterally as far.

check. This was due to rainy weather, which interrupted the planting; but as sixteen days elapsed between the planting and the inspection, there was doubtless ample opportunity for the transfer of all living root-lice from the weeds to the corn,—a conclusion to which I think no one will take exception who has been accustomed to observe the corn-field ant in charge of the corn root-aphis.

Additional to this, the difference in the treatment of the plats was the disking of the experimental plat three times and its harrowing once, and the differences between these plats with respect to ants and root-lice are to be taken as due to this additional and repeated stirring of the soil of the experimental plat.

June 10, two hundred and twenty-five hills, distributed over five different rows of the experimental (B) plat, were carefully examined by Dr. Folsom by digging up the corn and counting the ants and root-lice found upon the roots and in the hills. The rows chosen for these counts were taken from various parts of the field, being respectively the first, seventh, ninth, twentieth, and thirty-second of the entire plat. The last, it will be noticed, was the row next adjacent to the check plat. In the latter plat (A) seventy-five hills were similarly examined from the first, second, and ninetieth rows.

For convenience in comparison, the numbers given will be those for a hundred hills of corn taken as a unit. It thus appears (see Table I.) that twenty-eight per cent. of the hills of the check plat (A) were infested with ants, and that on the experimental plat ten per cent. of the hills were so infested; that seventeen per cent. of the check hills were infested by root-lice, and three per cent. of the experimental hills; that one hundred of the check hills contained 2263 ants, and one hundred of the experimental hills, 185 ants; that one hundred of the check hills contained 858 root-lice, and one hundred of the experimental hills, 79 root-lice. Or, more briefly stated, the untreated or check part of this field contained in equal areas, about twelve times as many ants and three times as many hills infested by them, and about eleven times as many root-lice and six times as many hills infested by them, as did the treated or experimental plat.

TABLE I. ABSTRACT OF COOLIDGE EXPERIMENT, 1904.

(Planted May 13-17 and May 25; examined June 10.)

	Plat A		Plat B	
	*Plowed (1), harrowed (2), cultivated (9) 75 hills examined		*Plowed (1), disked three times (3, 4, 5), harrowed (6), cultivated (7), harrowed (8) 225 hills examined	
	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills
Ants.....	28	2263	10	185
Aphids.....	17	858	3	79

1. Plowed May 14 to 16. 2. Harrowed May 17. 3. Disked May 18. 4. Disked May 21. 5. Disked May 25. 6. Harrowed May 25. 7. Cultivated May 28. 8. Harrowed May 30. 9. Cultivated June 9.

The Harvel Experiment. (Table II.).—In the second experiment, made on the farm of Mr. A. T. Doerr, near Harvel, in Christian county, a field of nine acres was divided into two parts, an experimental plat of three acres (Plat B) and a check plat (A) of six acres. In this field also the experimental plat consisted of thirty-two rows eighty rods in length.

The check plat (A) received no treatment until June 1, when it was spaded and harrowed. It was planted June 2 and harrowed June 13, the inspection being made the following day. On the experimental plat the stalks were harrowed down, raked, and burned May 13, the ground was plowed May 23, harrowed May 25, "spaded" on the 26th, and harrowed again on the 28th. At this time the field was practically free from weeds. On the 29th it rained all day, the first rain since the ground was plowed. This plat was spaded and harrowed June 1 and 2, and planted on the latter day. Rain followed on the 3d day of June, and the weather was wet until the 9th. The plat was rolled and harrowed on the 11th and cross-harrowed on the 13th, the inspection following the next day. In this case it will be noticed that the whole field was planted at the same time.

The harrowing to break down the stalks could scarcely have disturbed the ground sufficiently to interfere with the operations of the ants, and in a comparison of the plats that item may best be omitted. The difference in treatment is thus reduced to once plowing, once spading, harrowing three times, and rolling once, and to this

*Figures in parentheses refer to dates given at bottom of table.

the difference of the two plats with reference to ants and root-lice can fairly be attributed.

For a comparison of these plats seventy-five hills of corn were dug up in the check plat and one hundred in the experimental plat. Reducing the numbers given, for convenience of comparison, to a unit of one hundred hills, it appears (Table II.) that sixty-two per cent. of the hills were infested with ants on the check plat, and twenty-five per cent. on the experimental plat; that forty-four per cent. of the check hills were infested by root-lice, and eleven per cent. of the experimental hills; that one hundred of the check hills contained 1961 ants, and one hundred of the experimental hills, 630 ants; that one hundred of the check hills contained 1464 root-lice, and one hundred of the experimental hills, 198 root-lice. Or, more briefly and generally stated, and comparing equal areas of the two plats, we see that the check plat contained approximately three times as many ants infesting two and a half times as many hills, and seven times as many root-lice infesting four times as many hills as did the experimental plat.

The difference in apparent effect of treatment between the Galesburg field and the Harvel field may have been due to the fact that the Harvel field was much worse infested than the other. Twenty-eight per cent. of the hills were infested with ants at Galesburg and sixty-two per cent. at Harvel; and seventeen per cent. of the hills were infested with root-lice at Galesburg and forty-four per cent. at Harvel, with a difference of only four days in the dates of inspection.

Where both ants and root-lice are numerous, the chances that some of the former will find some of the latter after both have been thoroughly scattered through the soil, is doubtless greater than where both ants and root-lice are relatively few. Of course, as fast as root-lice or their eggs are recovered by the ants, whether originally the property of the ants or not, they will be appropriated and established on the plants in the field. Furthermore, later observations reported in this paper, have made it probable that ants actively convey their charges from one part to another of the field as conditions become less favorable where they were established. It is likely, consequently, that in a crowded field the root-lice would be carried over to plants lightly infested on the experimental plat, and that the normal results of the treatment would be thus to some extent masked or lost.

It is at any rate made certain by our later observations that as the food plant becomes crowded, much larger percentages of winged lice appear, and these, by emerging from the ground and scattering abroad, tend to diminish the ratio of increase in the over-infested field and to increase it elsewhere. Such a migration of winged lice

would still further diminish and mask the effect of the treatment. In other words, if an entire field is treated, the benefit will be greater than where only an experimental plat is used, and the results of treatment here given are less than they should be if they are correctly to indicate the probable effect of the procedure used.

It should be noticed further that the treatment of the Coolidge and the Doerr fields was different especially in the fact that the latter was harrowed three times while the Coolidge field was disked three times. As the harrow tooth does not penetrate the earth to so great a depth as the disk, and does not move the dirt so far or mix it so well, much of the difference in result is probably attributable to this difference of implements.

TABLE II. ABSTRACT OF DOERR EXPERIMENT, 1904.

(Planted June 2; examined June 14.)

	Plat A		Plat B.	
	*Spaded (5), harrowed twice (6, 9) 75 hills examined		*Plowed (1), harrowed (2), spaded (3), harrowed (4), spaded (5), harrowed (6), rolled (7), harrowed twice (8, 9) 100 hills examined	
	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills
Ants.....	62	1961	25	630
Aphids.....	44	1464	11	198

1. Plowed May 23. 2. Harrowed May 25. 3. Spaded (with spading harrow) May 26. 4. Harrowed May 28. 5. Spaded June 1. 6. Harrowed June 2. 7. Rolled June 11. 8. Harrowed June 11. 9. Harrowed June 13.

THE SEASON OF 1905. BRADFORD, ILLINOIS.

For a further test of agricultural measures against the corn root-aphis, I planned and provided for a field operation to begin as early as practicable in the spring of 1905, in a neighborhood in Stark county to which my attention had been especially called by the following letter of March 11 from Messrs. Deyo and Foster, real estate agents at Bradford, Ill.

"The farmers here are troubled with lice on the roots of the corn. Even on good ground we find that the roots are alive with them and the corn makes a very poor growth until about harvest-time. If we have rains it makes a fair yield, but blows over very

*See note to Table 1., p. 105.

easily. Will you please tell me what you know in regard to the matter, and what has been done on this subject."

Two assistants of the office, Mr. E. P. Taylor and Mr. E. O. G. Kelly, visited this neighborhood April 6 to 13, and after a careful survey of a large number of farms, selected three for special experiments, belonging respectively to H. B. Hinman, Edward Finnegan, and Frank Barto. Special observations were also made on the underground aphids in fields of corn and oats in comparison, on the farm of the F. H. Thompson Estate.

At the time of this first visit the root aphids were all still in the egg stage in the burrows of the small brown ant (*Lasius niger alienus*). The ants themselves were opening and extending their burrows, and the aphid eggs were found in clusters in carefully formed chambers about an inch under ground, in varying numbers, the maximum observed in a single nest being two hundred and seventy-five. The ants themselves had gone as deep as seven and a half inches, but no aphis eggs were found deeper than an inch. The fields were dry, and plowing had already begun. The soil was well pulverized, and many ants' nests had been turned over and covered up, but were not much broken up or scattered by the plow.

The first aphis egg hatched April 9, and several others from the same lot hatched the following day. The young as fast as they left the egg were placed by the ants on the roots of smartweed plants. Many of these weeds were from half an inch to an inch high, but many, barely sprouted and not yet out of the ground, had been found by the ants, and exposed by burrowing along them. The field work at this place was assigned to Mr. E. O. G. Kelly, who devoted his entire time to it for several weeks.

The weather of April and May was so unusually wet as to interfere materially with the intended treatment of the experimental plats. It also prevented as frequent access to the fields as was desirable for purposes of inspection, the exact comparison of check and experimental plats being indeed delayed until May 31, so long a time after treatment in some cases as to impair greatly the values of these comparisons. Illustrations of this point will be given in some detail in the general discussion at the conclusion of this paper. No precise record was kept of the rainfall, but the following memoranda will be of assistance in discussing the experiments.

A light rain fell April 6, but from the 10th to the 25th—the period of plowing—the weather was, on the whole, quite dry. April 27 and 28 heavy rains fell, but the fields were fairly dry again from April 30 to May 8. From the 9th to the 12th it rained hard and frequently, and the soil was continuously wet to the 15th, when it

rained heavily again, and daily thereafter to the 20th. Rains fell again on the 29th and 30th, and on the 4th of June.

The Hinman Experiment. (Table III.).—On the farm of Mr. Hinman, four and a half miles east of Bradford, was a field of seventy acres of corn, forty acres of which was selected for a field experiment. This had been planted to corn each year since 1902, and injury by the root-aphis on the higher parts of the field had been noticed in 1904.

This forty was divided, for the purposes of the experiment, into three strips. One plat (A) received the usual preparation of the land for corn. The stalks of the old corn were cut, and the ground was plowed from April 7 to 28, harrowed the first time May 3 and 4, pulverized with a disk harrow on May 5, and harrowed again May 8. Plat C was reserved for an experiment with minimum cultivation. The stalks were cut, and the ground was plowed April 7 to 28, like the preceding, and harrowed May 3 and 4 and again May 8. Plat B was set aside for an experiment with the effects of maximum cultivation, but repeated rains greatly hindered the farmer's work, and finally, as a consequence, this field was plowed like the others April 7 to 28, after the cutting of the stalks, was harrowed May 3 and 4, disked May 5 and again May 8, and harrowed also on the latter date. The preparation of these three plats thus varied as follows:—

Plat C (minimum cultivation) differed from plat A, the check, only in the fact that the ground was not disked. Plat B (maximum), on the other hand, differed from the check only in the fact that it was disked a second time. B thus differed from C by two additional treatments with the disk harrow. It will be noticed that all the plats were treated alike until May 5, when the ground of two of the plats was first disked, and that A and B received identical treatment until May 8, when the latter was disked a second time.

The entire field was planted on three different dates, the planted rows running crosswise of the plats. The first hundred rows on the north end of each plat were planted May 8, and, rains intervening, one hundred and sixty-four rows next south of these were planted May 13 and 15. Rains again followed, so packing the soil that the remainder of the field—one hundred and eight rows—was harrowed again (with an Acme harrow, sometimes called a pulverizer) and planted on the 22d and 23d of May. This last-planted section thus constituted a distinct division of the three foregoing plats, receiving one additional treatment with the Acme harrow, and being planted two weeks later than the first planting of a hundred rows and about a week later than the second planting of one hundred and sixty-four

rows. The extremes of treatment in this field, it will be seen, were between the part of plat C first planted and the part of plat B planted last, these two plats differing in the fact that the late-planted part of plat B was harrowed twice more (once with Acme and once with toothed harrow) and disked once more than the early-planted part of C.

Observations were made in the Hinman field by Mr. Kelly, at as frequent intervals as the weather permitted, during the period from May 2 until the planting was finished on the 23d. On May 2, where the ground had been merely plowed many young root-lice were seen in the field, which the ants were placing on young smartweeds. Five ants' nests, all within a space twenty feet square, were explored and found to contain from thirty to one hundred and thirty-five ants, from twenty to forty aphis eggs—green and about to hatch—and from thirty-five to eighty-six young root-lice, all of the first generation from the egg. The harrowing of the whole field May 3 and 4 stirred the weeds about and disturbed the ants and aphids, but seemed to kill neither insects nor weeds. The disk harrow or pulverizer loosened the soil to the full depth of the plowing, and scattered the ants and aphids greatly. On the 6th of May ants were everywhere on and through the soil, and an occasional aphis was seen on roots of grass or smartweed, seldom, however, with any ants in company. May 13, the ants were generally reestablished in the plowed part of the field, and many root-lice were collected from their burrows feeding on foxtail-grass and on an occasional volunteer plant of corn. Thirty-two ants' nests were dug out on this date, each containing from six to one hundred ants. In seventeen nests there were no root-lice, and in the remaining fifteen these varied in number from two to sixty-five. There were, on an average, twenty aphids to each nest containing them, all wingless, but many already full grown, and all apparently of the first generation from the egg. May 18, the corn planted May 8 was beginning to come up, and twenty-five hills were dug out. Ants were found in two; root-lice in none.

May 31, a test examination of this field was made by digging up in the earliest-planted portions of plats A, B, and C, fifty hills from each, and in the later-planted portions twenty-five hills from each plat. Although the number of hills dug up was perhaps too small to give satisfactory averages applicable to the entire field, Mr. Kelly tells me that the several lots were not taken entirely at random, but that each was carefully chosen with the idea of making it a fair and sufficient sample of its plat. In digging up the plants the whole root system was exposed, and all the ants and all the root-

lice were collected and counted for each hill. For convenience in comparison the data will be given in each instance for a hundred hills of corn taken as a unit. Those for the early and late plantings will be given separately—first those for the parts of the field which received the least treatment, and then, by successive steps, for those which were treated most. (See Table III.)

TABLE III. ABSTRACT OF HINMAN EXPERIMENT, 1905.

(Planted May 8, and May 13 to 15; examined May 31.)

	Plat A. 1		Plat B, 1		Plat C, 1	
	*Plowed (1), harrowed (2), disked (3), harrowed (4)		Plowed (1), harrowed (2), disked twice (3, 5), harrowed (4)		Plowed (1), harrowed twice (2, 4)	
	50 hills examined		50 hills examined		50 hills examined	
	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills
Ants.....	54	2012	26	744	64	2096
Aphids.....	40	838	12	158	48	974
	A, 2. Pulverized (6)		B, 2. Pulverized (6)		C, 2. Pulverized (6)	
	25 hills examined		25 hills examined		25 hills examined	
Ants..	24	260	12	66	24	194
Aphids.....	12	62	0	0	20	146

1. Plowed April 7 to 28. 2. Harrowed May 3 and 4. 3. Disked May 5. 4. Harrowed May 8. 5. Disked May 8. 6. Pulverized (Acme harrow) May 22 and 23.

In plat C, with minimum treatment, sixty-four per cent. of the hills were infested with ants; in plat A, with medium treatment, fifty-four per cent. were so infested; and in plat B, with maximum treatment, the percentage of infestation by ants was twenty-six. Forty-eight per cent. of the hills of plat C were infested by root-lice; forty per cent. in plat A; and twelve per cent. in plat B. One hundred hills in plat C contained 2096 ants; in A, 2012; and in B, 744. One hundred hills in C contained 974 root-lice; in A, 838; and in B, 158. In other words, taking the infestation of plat C as a basis of comparison, we find that the single additional disking of plat A reduced the number of *hills infested* by ants to eighty-four per cent., and those infested by root-lice to eighty-three

*See note to Table I., p. 105.

per cent., the number of *ants* per hundred hills to ninety-five per cent., and the number of *root-lice* per hundred hills to eighty-six per cent. Comparing similarly plat B with plat C, we find that the effect of disking twice was to reduce the number of hills of corn infested by ants to forty-one per cent., and the number infested by root-lice to twenty-five per cent., and also to reduce the number of ants per hundred hills of corn to thirty-five per cent., and the number of root-lice per hundred hills to sixteen per cent. Still more briefly stated, the root-louse infestation was reduced approximately fifteen per cent. by disking once; and seventy-five per cent. as to the number of hills infested, or eighty-four per cent. as to the number of root-lice in the field, by disking twice (see experiment 5, Table V.).

A comparison of the early-planted part of section C, in which fifty hills were examined, with the late-planted part of section B, in which twenty-five hills were examined, gives a surprising contrast. It will be remembered that all the latest-planted sections received an additional pulverizing just before planting,—necessitated, in the owner's judgment, by the packing effect of a heavy rain while the planting of the field was in progress. If this circumstance be taken into account, then it may be said that a comparison of these two areas indicates that three times disking—the last time soon after a heavy packing rain—may reduce the number of hills infested by ants to nineteen per cent., and the number of ants themselves to three per cent., and may obliterate the root-lice entirely, since none were found in the twenty-five hills searched in the late-planted part of section B.

The effect of a single disking, following closely upon a beating rain, as shown by counts made in each of the three sections before and after these events and by averaging the percentages for the three plats, is as follows: The hills infested by ants were reduced to forty-three per cent. and the ants themselves to ten per cent. of the number to be found in those parts of the field which had not been disked after the rain, while the root-lice were reduced by the same treatment, to thirty-six per cent. in the number of hills infested and to eleven per cent. in the number of insects in the field.

A further instructive conclusion may be derived from the observations of May 31 by comparing the product of fifty badly infested hills with the remaining 225 dug up on that day. The total number of root-lice found in the fifty hills was 5254, averaging over 105 per hill, while the total in the 225 hills was 1068, or an average of five per hill. If these two collections of root-lice be compared with reference to the percentage of the adults which have developed wings, added to the pupæ, which would acquire them at the next

molt, we find that this ratio of winged forms is much greater in the badly infested hills; that the ratio of winged specimens increases, in other words, with the crowding of the insects and the consequent pressure on their food supply. In the 225 slightly infested hills were 225 wingless adults and 54 winged adults and pupæ, a ratio of 21 per cent.; while in the fifty badly infested hills were 227 wingless adults and 349 winged adults and pupæ, a ratio of 64 per cent. of the winged form. That is, the winged insects were three times as numerous in the crowded colonies as they were in the smaller ones. It is quite probable that experiment will show that this increase of the ratio of winged to wingless specimens might be brought about experimentally by various means which have the effect to diminish the average food supply. It is to be expected, consequently, that mere drouth, if it goes to the extreme of injuring the plant infested, may have the effect to break the force of the root-louse attack by stimulating the development of winged specimens, which, leaving the earth and flying abroad, would give the infested plant a chance to rally against injury.

The Finnegan Experiment. (Table IV.).—On the farm of Edward Finnegan, one and a half miles northeast of Bradford, a field of eighteen acres was selected for experiment. This field had been planted to corn in 1904, to oats in 1903, and to corn for the three preceding years. A considerable injury, apparently due to the corn root-aphis, had been noticed in it in 1904. Two parts of this field, which may be called plats A and B, were treated as follows:—

Both were plowed April 18 to 21, disked May 22, harrowed May 23 and 24, and planted May 24. B differed from A only in the fact that it was twice disked in succession May 22, instead of once only on that date. Plat B was a strip running lengthwise of the field from north to south, and twenty-two rows wide, beginning on the west side; and plat A comprised the greater part of the field, extending eighty-eight rows inward from the eastern border. Smartweed and grass grew two or three inches high by May 22, heavy rains having by this time packed the soil very closely. The corn was put in about three inches deep, and began to show above the surface by May 30, on which date the first root-aphis was found in a hill of corn infested by *Lasius alienus*. These fields were examined June 9 for a test of the results of the single additional treatment with the disk harrow in which alone the two plats differed (see Table IV.). Fifty hills were examined from each plat, with the general result that in the check plat, A, seventy-five per cent. of them were infested by ants, and that in the experimntal plat, B, fifty per cent. of them were so infested. In the check plat, A,

seventy-four per cent. of the hills were infested by root-lice, and forty-four per cent. in the experimental plat. The former contained 3034 ants per hundred hills, and the latter 1746—fifty-seven per cent. of the first number. The latter, or check plat, also contained 2392 root-lice per hundred hills, and the former, or experimental plat, 1362 root-lice per hundred hills—sixty per cent. of the number in the first.

More briefly stated, the single treatment with the disk harrow May 22, following immediately upon an earlier treatment the same day (see Experiment 4, Table V.), had reduced the infestation by ants by forty-two per cent. in number of insects and by thirty-three per cent. in number of hills infested; and had reduced the infestation by root-lice by forty-three per cent. in number of insects and by forty-one per cent. in number of hills infested, the result being tested by a critical examination made sixteen days after the field was planted. In short, a single disking of the soil had diminished the infestation by ants and root-lice generally by something over one third.

TABLE IV. ABSTRACT OF FINNEGAN EXPERIMENT, 1905.

(Planted May 24; examined June 9.)

	Plat A		Plat B	
	*Plowed (1), disked (2), harrowed (4)		Plowed (1), disked twice (2, 3), harrowed (4)	
	50 hills examined		50 hills examined	
	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills
Ants.....	75	3034	50	1746
Aphids.....	74	2392	44	1362

1. Plowed April 18 to 21. 2. Disked first time May 22. 3. Disked second time May 22. 4. Harrowed May 23 and 24.

Observations on the Barto Farm.—A field of seventy acres, forty-five in oats and the remainder in corn, on the farm of Mr. Frank Barto, near Bradford, Ill., was selected for observation because of the extraordinary abundance of ants' nests containing aphis eggs to be found in various parts of it, and because of the history of the oats fields with reference to corn preceding, and of one of the corn fields with reference to oats. It was the principal object of the observations here made, to ascertain the effect on the corn root-aphis of a change of crop from corn to oats.

*See note to Table I., p. 105.

For the purposes of this discussion the field may be divided into two parts: one of twenty acres of corn which had been in that crop continuously for at least three years preceding—five acres indeed having been in corn since 1899; and the other of forty-five acres of oats, thirty-five acres of which had been in corn for three years preceding, and ten acres continuously in that crop since 1899 until sowed to oats the present spring.

April 27 several nests of *Lasius alienus* were explored, each containing numerous root-louse eggs and some root-lice. Above and immediately about the ants' nests the smartweed was withering and the roots were drained of sap, and in many cases blackened and decayed. The tunnels of the ants extended sometimes as far as a foot and a half from the main entrance, and ranged irregularly from a depth of an inch to about six inches. The root-lice were mainly on smartweed (*Polygonum*) roots, from sixteen to twenty on a single plant. In that part of the field which had been six years in corn and was to be planted to the same crop again this year, eighteen nests were found within a distance of two hundred hills; and in that part which had been in corn for the three preceding years, thirty nests were found between two rows three hundred and fifty hills in length. Twelve of the nests were explored in these parts of the field, five in the first mentioned and seven in the second. The ants in these colonies ranged in number from eighteen to one hundred and twenty-six, averaging fifty-seven each. Four of them contained from one hundred to three hundred larvæ and eggs of ants. All were plentifully stocked with the eggs and young of root-lice, whether in all cases, or even in the majority, those of *Aphis maidiradicis* (the corn root-aphis) it was impossible to say with certainty at that early date. Root-louse eggs varied in number from seventy-five to two hundred and seventy-five per nest, averaging one hundred and sixty-one, and young root-lice were found in numbers varying from two to seventy-eight, with an average of thirty-five, a total average of one hundred and ninety-six root-louse eggs and young to each ant's nest.

May 1, root-lice nearly full grown, together with many young, were taken from roots of smartweed and ragweed (*Ambrosia*) in that part of the field sown to oats this spring but in corn for three year preceding. Two hundred oats plants were examined on and near the nests of ants containing root-lice, but not a louse was found upon them. Here again smartweeds near the nests of ants were withered and the roots were dead or actually gone. Cavities and gangways had been made by the ants beside the roots of these weeds. The first root-louse of the second generation was seen in the field

May 3, although the eggs of the preceding year were not yet all hatched.

At this time an interesting and important comparison was made between the contents of ants' nests in fields of corn last year and those on which a single crop of oats had been raised. Every nest of the former contained numerous root-lice or their eggs, while thirteen nests of *Lasius alienus* found in the oats field in corn for the three preceding years were carefully explored, but not an aphis could be found in the possession of the ants. Later, a single colony of thirty-six ants was found with no eggs but with seventy-eight root-lice in their possession. These had very likely been carried in from an adjacent part of the field. In the absence of root-lice the ants seemed to be maintaining themselves, in part at least, by capturing beetles and insect larvæ, the remains of which were found in their nests.

On the other hand, in the oats fields which had been in corn for some years before, ants were now less abundant than in the adjacent corn, and the eggs and young of root-lice were common in their nests. In fourteen nests explored May 3, eight hundred and eighty-six ants were found, an average of sixty-three per nest, together with five hundred and sixty-five eggs and eight hundred and eighteen young of root-lice. This was an average of ninety-eight to each nest, and is to be compared with the average of one hundred and ninety-six root-lice and root-louse eggs per nest in the adjacent fields of corn.

By May 8 the second generation of the root-lice was abundant in the oats fields, but none of them had as yet acquired wings. Heavy rains fell on the 10th and 11th of May and at occasional intervals thereafter, and the muddy fields were not revisited until May 18. Then many ants were crawling about and making new burrows in the ground (each of which contained from two to ten ants, and no root-lice. Specimens of the latter, dropped near these new-made burrows, were promptly pounced upon by ants and carried under ground. The root-lice seemed to be less numerous than before, as if affected by the rains. On the 22d of May the fields continuously in corn were visited again, and fourteen nests of ants were dug out and the contents caught and counted. Five hundred and seventy-one ants were found in these nests, an average of forty-one each, and six hundred and fifty-five ant larvæ in eight of them. The aphis contents, on the other hand, had dwindled greatly, consisting of forty-six wingless adults, thirty-three pupæ, and one hundred and seventy-three young, a total average of thirty-seven to each ant's nest.

May 30 the oats fields were revisited by Mr. Kelly, in company with Mr. C. A. Hart, whom I had sent out from the office to inspect the situation, and to the astonishment of both not an ant nor an aphis could be found in the whole forty-five acres of this crop. As recent rains had fallen, it was at first surmised that the ants' burrows had merely been obliterated, but protracted search on the two following days, which were warm and bright, gave the same negative result. The smartweeds were now virtually all dead, and the oats were tall enough to shade the ground. The entire ant and aphid population of these fields had evidently abandoned them, and could not be traced.

June 22 another visit was made to this field, and prolonged search again failed to discover a single insect of either kind, although in the adjoining corn both ants and aphids were numerous, and in one of the fields, where nearly every hill was infested, considerable injury was being done. The field of corn which had been in oats the preceding year, and in which on previous visits ants were found but not a root-louse, was now badly infested, and this fact offered the only possible hint of the whereabouts of the insects which had left the oats the preceding month.

Observations in the Thompson Field.—For further evidence concerning the effects of a change from corn to oats, observations were made by Mr. Kelly on two adjacent fields of forty acres each, one in corn this spring and the other in oats, both fields having been in corn continuously for the three years preceding, and both being heavily infested by *Aphis maidiradicis* May 8, when first selected for this comparison.

May 19, the ground being very wet after a recent rain, eight ant hills were examined in the oats field and their contents collected. Three hundred and thirty-four ants were obtained, an average of forty-two to each colony, and one hundred and sixty-seven aphids, an average of twenty-one to each ant's nest. Fifty of these aphids were wingless adults and eight were pupæ, the remainder, of course, being young in various stages. These were contained in seven of the nests, one nest being without root-lice. The number varied from two to forty-six to a nest.

The other field had been plowed for corn April 28 to May 5, and harrowed twice. Hard rains following, it was disked twice May 19 and 20, and harrowed again just as it was planted. Both ants and root-lice were found in this corn May 20, but no record was made of their number or distribution until June 2, at which time a final visit was made for a comparison of the two fields.

In the oats not an ant nor an aphid could now be found; even the borders of the field nearest the corn had been completely aban-

doned by both. In the corn, from a hundred hills chosen as fairly representative of the whole field 2156 ants were taken, an average of twenty-two to the hill, fifty-two of the hundred hills being infested by them. In the same hills 1507 root-lice were found, an average of fifteen to the hill, forty-three of the hills being infested. Each ant's nest contained on an average forty-one ants and thirty-five root-lice,—less than one root-louse to each ant. The winged lice in these hundred hills averaged in number twenty-seven per cent. of all the adults. Collections made on higher and drier parts of the field were compared with those from lower and wetter portions, but gave no marked difference in respect either to the ants or aphids, or to the ratios of winged to wingless adults.

Observations made in this field correspond precisely, it will be seen, to those reported from the Barto fields with reference to the total disappearance, late in May, of ants and aphids from oats grown on old corn ground.

ADDITIONAL MISCELLANEOUS OBSERVATIONS.

April 11, at Bradford, an ant's nest was explored, the burrows of which extended throughout an area approximately three by four feet, and to depths varying from one to four inches. Ants were distributed everywhere through the soil within these dimensions, but all the aphis eggs seen were collected at one place.

April 12, a nest of *Lasius alienus,* around which a few young smartweeds (*Polygonum persicaria*) about one inch high were scattered, was watched by Mr. Kelly for two hours and a half. An ant coming up with a young root-louse in its mandibles carried this about two feet and placed it on a smartweed very near the ground, and the root-louse, after crawling about half an inch, thrust its beak into the plant. Six more ants transferred a single root-louse each to smartweeds above ground within the next twenty minutes. In about an hour and a half one of the ants returned its root-louse to the nest, and thirty-five minutes later all had been carried back. One of these ants, which was so marked that it could be recognized on its return, recovered and carried to the nest the same root-louse which it had previously brought out.

Another nest of the ants was carefully explored on the 13th. The burrows were found to vary in diameter from one sixteenth to three eighths of an inch, and to range from one to six inches below the surface. In a cell a quarter of an inch in diameter were many eggs and a few young of the corn root-aphis. When these were disturbed the ants seized them and retreated to more distant parts of

their habitation. About two inches from this collection of eggs a smartweed root had been exposed by the ants under ground, and on this about fifteen of the root-lice were feeding.

In another nest explored on the same day the burrows were from one tenth to one eighth of an inch in diameter. Under a space of two square feet four clusters of root-louse eggs and some recently hatched aphids were found. Six young aphids on the roots of a smartweed in one of these burrows were promptly seized by the ants and carried farther into their retreat. At four o'clock p. m. most of the ants had retired for the day, but two brought out an aphis each, taking it back, however, in less than two minutes. Twenty-two ants were found in this nest, together with a bunch of aphis eggs about as large as a pea. Two inches from this mass of eggs was a sprouting smartweed that had not yet broken ground, and on it were a number of young root-lice. When exposed by digging, the ants immediately seized them and carried them away. Roots of smartweed, grasses, and ragweed exposed in burrows, sometimes had no root-lice on them, although in one case a root-louse was found on a ragweed root.

May 5 ten nearly grown aphids were taken from a smartweed root and placed on the bare ground. They crawled actively about and two of them entered a crack in the earth as if to escape the light. One of these was found by an ant which carried it away. Two small ones crawled about four feet and stopped as if exhausted, but two larger aphids traveled more than ten feet in an hour and twenty minutes. All these aphids were seemingly averse to the light, and crawled away from the sun.

May 8 several young of the second brood were found. Three full-grown stem-mothers were unearthed, near one of which were four young, and near another, two. The third was in the act of giving birth to an aphis, of which an ant took possession as soon as it was born and carried it to a new plant. Presently all the other young were carried away by ants and placed on plant roots. A second aphis was born from the same mother within forty minutes after the first. This also was soon carried away and placed on a fresh plant.

On the 9th, which was cool and damp, a heavy rain having fallen during the morning, the ants were seen taking the root-lice from the old smartweed roots—which were now dead and dry or even decayed—and placing them on the roots of younger plants.

On May 12 Mr. Kelly took a corn root-aphis from a plant and placed it on the ground. A root-louse ant (*Lasius alienus*) found it presently, carried it away to a distance of four feet, placed it on the

ground, made a burrow to the root of a plant of foxtail-grass (*Setaria*) and put the root-louse on the plant, where it was afterwards found by digging. Presently she took the root-louse away again to a new place, and finding a root of foxtail exposed in a crack of the earth she placed the aphis on it, and there the insect remained until the observation closed.

April 23 a *Harpalus caliginosus* was found in an ant's (*Lasius alienus*) nest, where it was surrounded by several fragments of ants which it had evidently been eating. April 26 another harpalid was captured under a board, where it was eating ants and was surrounded by fragments of those already devoured.

April 29 the remains of four seed-corn beetles (*Agonoderus pallipes*) were seen in an ant's nest which contained about two hundred ants, but no root-lice. May 15 a *Lasius alienus* was found feeding on an earthworm.

Systematic breeding-cage experiments, made in my insectary at Urbana with eggs and aphids sent in by Mr. Kelly, gave results substantially consistent with those previously published* as to periods and succession of generations, but yielded a much larger number of young for each mother aphis than I have previously reared. The largest number hitherto reported was fifteen young, and the average reared was much less than that. This year, however, thirty-six adults bred between July 1 and September 14 produced from twenty to eighty-four young each, with an average of forty-one to each parent, and this may probably be accepted as the known rate of multiplication under favorable conditions. The period of development from birth to reproductive maturity, as shown by the birth of the first young, varied from seven to ten days for twenty-three specimens, the average being 8.4 days. The time from the appearance of the first young of any parent to the birth of the last young of the same parent varied, in thirty-six cases, from 6 to 20 days, with an average of 10 days, and this may be taken as the ordinary length of the reproductive period in midsummer under insectary conditions.

General Discussion of the Results (Table V.).

The most pronounced effect of an early treatment of the soil for the control of the corn root-aphis was produced on the Coolidge farm in 1904, where disking three times and harrowing once reduced the number of hills infested by ants by sixty-four per cent., and those infested with aphids by eighty-two per cent., and the number of insects, both ants and aphids, by ninety-two per cent. each.

*Eighteenth Rep. State Ent. Ill., pp. 63-64.

In this case the field was disked on the 18th, 21st, and 25th of May, harrowed on the latter date, and examined June 9, fifteen days after the last treatment.

More remarkable, on the whole, was the effect of once harrowing with an Acme harrow May 22 and 23, after numerous heavy rains from the 15th to the 20th of May, 1905. Here a single treatment (Experiment 3, Table V.) with the disk harrow, used as soon as the ground was dry enough to work properly, reduced the number of hills infested by ants and aphids by fifty-eight per cent. and sixty-four per cent. respectively, and the number of insects in the field by ninety per cent. for the ants and eighty-nine per cent. for the aphids.

The least effective treatment, according to Mr. Kelly's notes, was a single disking, May 5, of plat A1 on the Hinman farm (Table III.), which, as shown by a comparison with C 1 of the same table, seems to have reduced the number of hills infested by only sixteen per cent. for the ants and seventeen per cent. for the aphids, and the number of insects by four per cent. for the former and fourteen per cent. for the latter. As these plats were not examined until May 31, that is to say twenty-six days after the treatment, these figures probably ought not to be taken into account. It was hardly to be expected that the original difference between check and experimental plats should continue unchanged during this interval of nearly four weeks.

Five of the pairs of plats brought into comparison differed in respect to treatment only by the fact that the experimental plat was in each case treated with a disk harrow once more than its corresponding check. If the ratios for these five plats be averaged, it appears that the result of a single disking in 1905 on the Hinman and Finnegan places may be described in general terms as reducing the number of hills infested by forty-four per cent. for the ants and fifty-one per cent. for the aphids, and the number of insects by fifty-seven per cent. for the ants and sixty-three per cent. for the aphids. Or, still more generally speaking, it may be said that the average effect of a single treatment with the disk harrow was to reduce the number of infested hills by a little less than half, and the number of insects in the field by about two thirds. If, in view of the doubtful character of one of these comparisons above mentioned, in which nearly four weeks intervened between the experimental operation and the inspection of the plats, we omit this case from our calculation, this statement may be revised to the effect that a single disking may be expected to reduce the number of infested hills by something more than half, and the number of insects in the field by nearly three fourths.

The effect of twice disking, as shown by a comparison of C 1 and B 1 of the Hinman field (Table III.) was to reduce the number of infested hills by fifty-nine per cent. for the ants and seventy-five per cent. for the aphids, and the number of insects by sixty-five per cent. and eighty-four per cent. respectively. As these two treatments were given, however, on the 5th and 8th of May, and the inspection was not until twenty-three days later, it is probable that the full effect of this treatment does not appear in this statement of the result, since there was ample time for the treated plats to become restocked by both ants and aphids by multiplication and migration and by the establishment of new aphis colonies from winged parents developed during this interval.

The general conclusion to be drawn from this whole series of experiments is to the effect that the number of both ants and aphids may be readily controlled and the injuries to corn in great measure prevented by thorough and frequent stirring of the ground previous to corn planting, and that the disk harrow or its equivalent is much the best implement for the purpose. Indeed, the treatment most effective for the destruction of the root-aphis and its attendant ant in spring is in great measure that which will be found most useful as a thorough preparation of the soil for corn, the main difference being that a thorough overturning and stirring of the soil is the essential thing for the destruction of the root-louse, while it is sufficient for the corn plant if the earth be merely pulverized in place.

If the corn farmer will prepare his old corn ground early and thoroughly, using the plow and the disk harrow by preference, he should have little trouble in the beginning of the season from the corn root-aphis, and so fast and so far as the general community acts in accordance with this idea, to that extent will later injuries by this aphis be forestalled. It is in this as in many other cases, one acting by himself alone can accomplish relatively little even for his own protection; the welfare of each depends on intelligent cooperation by all.

It is further to be concluded from the observations here reported, that if infested corn ground be planted to oats, the root-lice will leave it or perish in it (just which we do not yet know) by the end of May. A rotation with a short period in corn must consequently act to check the multiplication of this insect and to diminish its injuries to corn.

TABLE V. COMPARATIVE EXHIBIT OF RESULTS OF TREATMENT.

Experiment	Differential Treatment	Percentages of Reduction			
		Ants		Aphids	
		Hills infested	Number of insects	Hills infested	Number of insects
1. Coolidge.....	Disked three times, harrowed once..	64	92	82	92
2. Doerr	Plowed once, harrowed three times	60	68	75	81
	Spaded once, rolled once.....				
3. Hinman.....	Disked once, (after heavy rains). ..	58	90	64	89
	Disked once, (after harrowing).....	52	63	72	81
4. Finnegan.....	Disked once, (after previous disking)	33	42	41	43
5. Hinman	Disked twice.....	59	65	75	84

FIELD EXPERIMENTS FOR THE PROTECTION OF CORN AGAINST CHINCH-BUG INJURY.

BARRIER EXPERIMENTS.

Experiment of 1895.—In my ninth entomological report, published in 1898, I gave an account, in an article on "Midsummer Measures against the Chinch-bug,"* of a field experiment made in

*Twentieth Rep. State Ent. Ill., pp. 37–44.

1895 for the destruction of that insect as it passes in June and early July from small grain to corn. The measures used in this experiment were a combination program of a dusty furrow for the arrest and destruction of chinch-bugs in dry weather, a coal-tar line with post-hole traps for use when the ground is too wet to pulverize, and kerosene emulsion for the destruction of the insect on the corn itself.

This operation, carried on in Effingham county from June 5 to 15 by one of my assistants, was highly successful in the protection of corn growing adjacent to a heavily infested 20-acre field of wheat, approximately twelve bushels of chinch-bugs being destroyed in the process at a cost of less than five dollars for the materials used.

Extreme conditions prevailed at the time of this experiment. Injury by chinch-bugs to grass, small grains, and corn had continued in this locality for some years with increasing intensity, and these insects had become so numerous in the wheat that they had already destroyed the crop and virtually all other grass-like vegetation in the field referred to, by the 5th of June. Compelled to leave the wheat to avoid starvation, they moved out of it rapidly, wholly deserting it within a very few days. The corn adjacent was thus exposed to immediate and complete destruction by the invading horde, and would inevitably have been soon destroyed if active measures had not been taken to protect it, a fact made perfectly apparent by the fate of other similarly situated fields in the neighborhood.

The weather of the season had been very dry, and it was intensely hot, conditions which, although unfavorable to the infested crops, were unusually favorable to the easy success of measures for the destruction of the chinch-bugs. A dusty furrow, readily made and maintained between the wheat and the corn, trapped the insects in myriads as they attempted to pass from one field to the other, and the heat of the dry dust in the bottom of the furrow,

fully exposed to the sun, speedily killed them. The coal-tar barrier was, in fact, required but once, and the kerosene emulsion was used only to destroy the bugs which had entered the field before the experiment began and a few which escaped into it in an interval between a shower of rain and the establishment of the tar line. As the protected field of corn bore a good crop while other fields in the neighborhood were almost wholly destroyed, the demonstration of the usefulness of this method was complete for these extreme conditions.

Experiments of 1904.—Wishing to know, however, what might be done by similar operations under more ordinary circumstances, especially when a chinch-bug outbreak was but just beginning and when the weather was generally unfavorable to success, I prepared in the spring of 1904 for several field trials, to be made at different places in southern Illinois where a previous inspection had shown that the chinch-bugs were present in numbers sufficient to threaten more or less injury to wheat and corn. The fields selected were in four localities: near Carbondale, in Jackson county; near Dubois, in Washington county; and near Fairman and Odin respectively, in Marion county.

The experiment was placed in charge of Mr. E. P. Taylor, and I owe the results here reported to his energy and faithfulness in the field, and to the fulness and exactness of his notes.

Although the prospect of insect injury was considerable at all these places in the early part of the year, the weather of the spring and early summer was so wet and much of the time so cool that the multiplication of the insects was in great measure prevented, and they finally became abundant enough to injure corn seriously only in the Carbondale neighborhood. The whole experiment was faithfully carried through, however, at all the above places, and with useful results at each.

At Carbondale, rain fell twelve times and on eleven different days between June 24 and July 25, and the ground was kept so moist by rains at all the places mentioned that the dusty furrow could not be long maintained at any of them. As a consequence, the tar line, with post-hole traps, was used throughout, and kerosene emulsion was only occasionally applied, as found necessary.

The tar lines laid at these various places aggregated more than a mile and a half in length (508 rods, exactly), and were maintained for periods varying from eleven to twenty-eight days, the total of this procedure being equivalent to the maintenance of an effective coal-tar barrier a mile in length for twenty-seven days. Post-holes were dug from one to two feet deep at a usual distance of

twenty feet apart along all these lines; and besides the continuous coal-tar strip, diagonal leaders about a foot in length were laid from each hole outwards in two directions, as shown in the accompanying diagram (Fig. 2, p. 131).

SUMMARY OF CONCLUSIONS.

As a general outcome of the work at these various places, it was demonstrated that an effective barrier against the movement of chinch-bugs may be maintained for four weeks with coal-tar, poured along a strip of ground properly prepared, at a cost for materials of seven cents a rod, or $22.40 a mile, and that virtually all the bugs approaching these lines may be trapped and killed in post-holes properly placed for the purpose.

The time for which this barrier must be kept intact will vary from ten days, the period found necessary in the very dry weather of 1896, to thirty days, as required this year. The labor necessitated is that of raising a ridge by plowing a back furrow between the infested field and the one to be protected, smoothing and packing this strip with a light roller or by hand, digging a row of post-holes at intervals of about twenty feet, and laying the lines of tar by pouring it upon the ground from a can with a tubular spout. This line was renewed whenever it became dry or hard in the sun, or when it was covered with dust in windy weather or washed away or covered with mud by rains. It was necessary to pour fresh tar along the line from one to three times a day, the average at all places for the month being three renewals every two days.

USE OF KEROSENE EMULSION.

Where chinch-bugs had entered corn before the experiment was begun, and where, through accident or mismanagement, they escaped across the barrier, they were effectively treated with a four per cent. kerosene emulsion. It was shown that a mixture sufficiently complete and lasting for the purpose could easily be made by stirring the kerosene and the soap solution together with a stick or paddle, and that this emulsion could be conveniently applied by sprinkling or throwing it on the infested plants with a whisk-broom, or even with the bare hand. Thus prepared and used, the four per cent. emulsion was as strong as the corn would stand without some injury, and was sufficient to kill all the chinch-bugs which it touched.

The only notable failure of this method to destroy the chinch-bugs against which it was used, occurred where the infestation of

the wheat field was slight, and where so many grass-like weeds had sprung up in the wheat that they afforded food to the bugs in the field at harvest sufficient to detain them there for several days. There was virtually no migration on foot out of this field, the chinch-bugs generally lingering until the appearance of their wings enabled them to scatter by flight to more favorable breeding grounds.

At Carbondale, where they were the most abundant, the corn adjacent to infested wheat was saved from all injury worth noticing, while the crop on some other fields in that region not protected, was completely destroyed for many rods inward from the edge of the field, and badly injured for a considerable distance further.

The Carbondale Experiment.—On a farm situated one mile west of Carbondale, belonging to Mr. Robert Thorpe and referred to in this account as the Thorpe farm, was an irregularly shaped field of one hundred and forty acres of wheat which in June, 1904, was generally and considerably infested by chinch-bugs, sufficiently so to threaten notable injury to the wheat crop itself and the destruction at harvest-time of much of the corn adjacent. Indeed, by the last week in June the wheat was ripening irregularly, turning brown in patches where the chinch-bug was most abundant, in advance of the general ripening of the field, and from these patches the insects were already beginning to move into other crops.

A corn field of twenty-seven acres cornered into this wheat at the northwest in such a way that the division line of the two crops measured three hundred and seventeen yards on the east and three hundred and thirty-eight yards on the south, the remainder of the southern side being bounded by woodland. In the southwest corner of this wheat was another field of corn of only four acres, so placed that it was bounded by infested wheat only on one side for about one hundred yards. A third field of corn, on an adjacent farm belonging to Ralph Thompson, was also exposed to invasion from the wheat field for a distance of about one hundred and forty yards. This corn was south of the wheat, from which it was separated by a roadway of the usual width.

The situation here was complicated by the fact that in the northwest field of twenty-seven acres of corn a large pile of waste from a corn shredder had been left the preceding fall, in which quantities of chinch-bugs had passed the winter. Coming out in spring, many of these laid their eggs in the young corn, which thus became immediately infested from within by the first generation of the year. A part of the wheat bordering this field on the south had ripened early, owing perhaps to chinch-bug injury, and the bugs from this vicinity had already begun to invade the corn before our experiment

was begun, infesting a strip about thirty yards in length and seven or eight rows deep.

To prevent the further entrance of chinch-bugs into these three corn fields from without, 1080 yards (about three fifths of a mile) of impassable barriers were required, with approximately 160 post-hole traps distributed along them; and to destroy those already in the field before our work began it was necessary to spray a part of the northwest field with kerosene emulsion.

When these premises were taken in charge for our purpose by Mr. Taylor, June 23, 1904, the wheat was already nearly ripe, and harvesting began a few days later, continuing until July 7. The chinch-bugs were at first by no means hurried in their movement out of the wheat, as there were still grassy weeds in the stubble to detain them, and the frequent showers of the following month kept this vegetation in good condition continuously. The movement towards the corn was well marked, however, from the beginning, and prompt measures were necessary to protect that crop. There was also urgent need for a destruction of chinch-bugs already in the corn, and this was the first task undertaken, kerosene emulsion being made up to June 23 in a rather rough-and-ready manner by stirring the kerosene and soap-suds together vigorously for several minutes with a stick. This mixture was then flirted on to the corn with the naked hand at a rate of about a pint to every three hills. The first mixture contained five per cent. of kerosene, and was evidently too crudely made, proving injurious to the corn, especially where it was held in the conical cavity formed by the terminal tuft of leaves. It was estimated that about twenty-five per cent. of the stalks treated on this first date were damaged more or less. A four per cent. mixture, on the other hand, as applied on the 24th of June, did no damage to the plants, and is reported to have killed the chinch-bugs as soon as it touched them. This emulsion was used from time to time thoroughout the whole period of the experiment in parts of two fields of corn where the bugs made their way around the ends of the barriers in number to require special measures for their destruction.

An effort was made at the very first to use a dusty furrow as a barrier, with post-holes dug in the bottom to trap the bugs, and about one hundred and sixty rods of such furrows were made June 23 to 25 on the eastern and southern sides of the northwest field, and on the west side of the four-acre patch. The ground was deeply plowed and thoroughly harrowed in a four-foot strip, and a ridge was formed by making a back furrow down the middle. A log was then dragged through the center of the strip until a dusty groove

or furrow was made several inches in depth. In the bottom of this holes were dug with an ordinary post-hole digger at intervals of twenty feet. The ground was too damp, however, even at first, to make a satisfactory barrier, and heavy rains falling on the 24th and 25th of June compelled a prompt abandonment of this part of the operation.

Coal-tar lines, substituted for the furrow because of the weather, were laid on the 24th to the 26th so far as needed to protect fields of corn on the Thorpe farm. June 30 it became necessary to lay also a similar line for a short distance along the border of the south field on the Thompson farm, as the hungry bugs were at this time crossing the road in large numbers on their way to the corn. All these tar lines aggregated about two hundred rods in length, and were maintained in an effective condition around the different fields from eighteen to twenty-eight days. It was necessary to renew them, on an average, twice every three days. One hundred and forty-five gallons of tar were used in all, at a cost of $8.85. The supply of tar being temporarily exhausted July 9, kerosene was poured along the dried-out line on the ground, with the effect to soften it and to keep it soft for thirty hours. Besides the hardening of the tar by exposure to the sun, the barriers were occasionally bridged by dust blown into them, and broken by rains which sometimes washed them away in spots or covered parts of them with mud.

It is needless to say that no chinch-bugs crossed the tar line as long as it was kept reasonably fresh. The post-hole traps, into which the bugs were led by diagonal lines or leaders of tar, worked effectively, and bugs accumulated in them in variable amounts up to a quart for each hole. Here they were readily killed by pouring a little tar-water or kerosene upon them.

The movement of the bugs was greatly influenced by the weather. On warm and sunny days they sometimes began to travel not long after sunrise and continued until near sunset, but in cool and cloudy weather they moved later or not at all, and the traps consequently caught few or none. Whatever the weather, they never traveled at night. July 1 to 5, when the last of the wheat was being cut, they left the field more rapidly, and more of them were then destroyed than at any other time. By the 24th of July the movement was practically over, most of the bugs remaining having finished their growth and got their wings. Many of them had but recently transformed, as shown by their paler color, and pairing for the next generation was actively in progress.

The final result of the above operation is given in Mr. Taylor's report of conditions July 30, at which time he says that "all the

fields of corn which have received the protection of our barriers are quite uninjured and practically free from chinch-bugs." The small sprinkling of the insects to be found in any of the fields had doubtless flown in as they reached maturity. The actual cost for coal-tar was $8.85, and for kerosene and soap it was $2.55. The labor necessary to the operation was 28 days' work of a man and 2 of a team, the latter for making the back furrow, for rolling the ground, and for hauling the tar and kerosene emulsion to the field.

It should be noticed that this defensive operation was as complete and as expensive as would have been necessary if the chinch-bugs had been ten times as numerous in the wheat. That is, the labor and cost would have been no greater to protect the corn against the danger of a loss ten times as great as it would have suffered if the bugs actually in the wheat this year had been allowed to go their way.

The Fairman Experiment.—Near Fairman, in Marion county, a large field of wheat on the farm of Mr. Wm. Meredith, moderately infested by chinch-bugs, was selected for experiment. This field was bordered for eighty rods by a field of corn, from which it was separated by a wire fence. Operations were begun here June 30, when the wheat was already ripe, harvesting being in progress at the side of the field farthest from the corn. To protect the latter crop a double barrier was made within the margin of the wheat field, where two swathes of the grain were cut to give room for the operation.

A strip five feet wide the whole length of the field was plowed and thoroughly pulverized, and a deep dusty furrow was then made in the middle of it; and a strip two feet outside this was also prepared for the tar line, various parts of it by different methods.

Preparation of the Dusty Furrow.—Although wet weather prevented the continuous use of the dusty furrow as a barrier to the movement of the chinch-bugs, and compelled a reliance on the coal-tar line instead, the method used in preparing the former is well worthy of description. First, a furrow was plowed about seven inches deep and fourteen inches wide the whole length of the field in the center of the stubble border. On the return a second furrow was made immediately beside the first, the dirt from which was thrown back into the first furrow, leaving no unplowed earth between them. The land was then widened by plowing back and forth, throwing the earth toward the center each time, until six furrows had been made. This strip, about six feet wide, was then harrowed ten times with a common disk harrow, and twice with a straight-toothed harrow, leaving the ground level, thoroughly pulverized,

and free from clods and weeds. Next, near the center of this pulverized strip a deep dead furrow was made by plowing twice back and forth in the same line,—once in each direction with an ordinary fourteen-inch plow and once with a small diamond plow,—and in the ditch so made, a log eight feet long and eight inches through was dragged by a single horse (a mule would have been better) until the sides of the ditch were pulverized to the finest dust. This work would require, for an eighty-rod line, the labor of two men and a team for a little more than half a day. The average cost of a dusty furrow constructed as above described, would be practically three cents a rod, as shown by the actual labor of man and horse used on this eighty-rod line.

This furrow was finished July 3, and caught and held the chinch-bugs generally during that day and the following; but July 5 a heavy rain fell which put it out of service, and even the following day the ground was too wet to renew it by dragging again with the log. Equally heavy rains falling on the 8th and on the 11th discouraged further work with it, and it was practically abandoned in favor of the tar line.

When in use, some method of destroying the bugs entrapped is necessary. In bright summer weather the dust in the bottom becomes so hot as to kill all the chinch-bugs except those with wings, and many of these also will succumb. Otherwise, shallow pits may be dug with a post-hole digger or spade at intervals in the bottom of the furrow, care being taken to restore the dusty surfaces disturbed in this operation. The harassed bugs will accumulate here in quantities, and may be killed by pouring a little kerosene upon them. Experiments described on another page of this report indicate that the bugs caught in the dusty ditch may also be quickly killed by a brief exposure to a kerosene spray or to the flame of a gasoline torch.

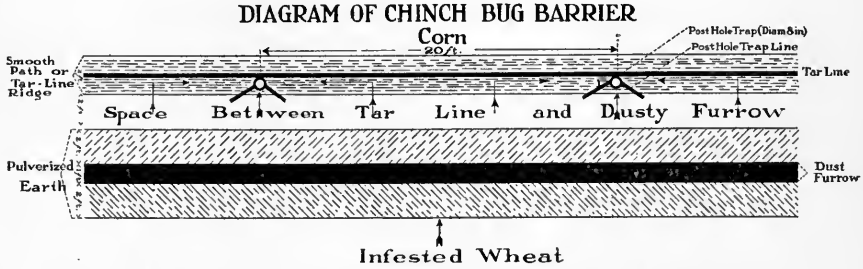

Fig. 2. Dusty furrow, and coal-tar line, with post-hole traps and diagonal "leaders" of tar.

Preparation of the Coal-tar Line.—To receive the tar line it is necessary to have a smooth hard band of earth like a well-beaten path, into which the tar will not readily sink. This should be about

level with the adjacent surface or a little above, as otherwise the line is likely to be bridged by dust and rubbish blown upon it. The effectiveness of the barrier depends, indeed, largely upon the preparation of the strip of earth along which the tar is to be poured. Such a path was prepared in six different ways on as many sections of the line.

Beginning at one end, a strip ten rods long was prepared beside the fence by simply scraping smooth with a hoe and sharp spade. Where the ground is hard, and grass and weeds form a thick mat, one man will not ordinarily clear over five rods an hour. This method is laborious and expensive, and would only be necessary where a team could not be used. It would cost for labor about two cents a rod.

The second section of ten rods was prepared by plowing two very shallow furrows with a fourteen-inch plow, merely skimming away the weeds, grass, and surface roots. Both these furrows threw the dirt towards the wheat field, leaving a belt about two feet wide free from weeds and grass, and separated from the wheat by the dirt thrown over. The work was thus done rapidly, but by this method the bare strip is left lower than the general surface and is liable to be covered in places with dust and weeds by the wind. It must also be smoothed here and there with a hoe before the tar is laid down. Eighty rods can be prepared in this way by one man and a single horse in half a day.

The third section of ten rods was made ready by plowing a back furrow in the stubble and beating the ridge of earth flat and hard with spades. This was one of the most satisfactory of the methods used, as by it the tar line is placed on a ridge where it is not likely to be bridged either by winds or rains. The comparatively loose earth will at first absorb the tar more freely than the hard bottom of a furrow, but this difference is not noticeable after a few days. A ridge of this kind may be more rapidly prepared by using an inverted trough-like drag of planks, weighted if necessary, to compact the earth, as has been done in Kansas on a large scale. This will take, for an eighty-rod line, the work of a man and team for about half a day.

The fourth ten-rod section was prepared by plowing a very shallow furrow with a single horse along the edge of the grass in the headland next the fence, throwing the dirt upon the stubble. This was not a satisfactory operation, however, as it left too narrow a smooth surface.

The fifth section, forty rods in length, was prepared by simply scraping away the weed and grass roots as clean as possible with an

ordinary farm scraper, making a strip about two feet wide, one or two inches below the general level. It was necessary, however, to scrape the surface afterwards with a shovel or hoe, as many irregularities were otherwise left to carry the tar in all directions. The labor of a man and team for half a day would be required to prepare eighty rods in this way.

Finally, the sixth section, eighteen rods long, was made in meadow land by plowing two shallow furrows, throwing the dirt outward in a way to leave a level dead furrow about two feet wide, and smoothing and leveling the bottom more exactly by hand. This is a rapid and satisfactory method of preparation where a barrier can be made in sod with room to work a team.

The tar line was made by pouring from a watering can a slender stream of tar continuously along the ground. Holes were then dug with an ordinary post-hole digger to a depth of about a foot and at a distance of twenty feet apart. They were placed on the stubble side of the line, and short diagonal lines of tar were laid from each hole to the right and left in a way to conduct chinch-bugs approaching the line to the hole itself. Six gallons of tar were needed to construct this barrier along the eighty-rod boundary. During the period of twelve days covered by this experiment, the tar line was renewed eighteen times in all, as many as three times a day at first, while every other day was sufficient towards the end of the period. Fifty-five gallons of tar were used in these eighteen operations, an average of three gallons for each time. The cost of the tar for this period was $2.40, or twenty cents a day for the twelve days. This line was of course effective from the first, and bugs were continuously caught in the holes along it, where they were easily killed with tar-water or kerosene.

Dubois and Odin Experiments.—At Dubois, in Washington county, an irregular field of corn containing twenty-eight acres was protected from invasion by chinch-bugs from two fields of wheat adjoining it. On the east side along a boundary line of two hundred and fifty yards a double barrier was constructed, a furrow next the corn and a tar line with post-holes immediately outside. To the west and north a tar line was laid seven hundred and sixteen rods in length, and post-holes were dug every twenty feet. Although the chinch-bugs proved not to be sufficiently numerous in the wheat to have caused any great injury even if they had escaped into the corn without hindrance, these barriers were as carefully maintained for eleven days, from June 29 to July 10, as if the salvation of the corn depended upon their efficiency.

At Odin was a small field of infested wheat, containing four acres, with corn bordering it to the north and west. A tar and post-hole line was carried along these two sides for about a thousand feet to prevent the passage of the bugs across the boundaries.

The conditions and results at both these places were so similar to those at Fairman that no detailed account is necessary. At Odin a simple method was made use of for preparing the ground for the tar. A heavy plank was dragged endwise back and forth about ten times along the edge of the wheat, thus smoothing and packing well a strip two feet wide. With a short-handled shovel the ground was then packed and pounded to a hard surface, in which a narrow and shallow groove was made with the shovel handle for the reception of the tar. This was poured in a stream the size of a lead-pencil from the spout of a watering-pot from which the sprinkler had been removed. The line so laid spread out on the ground to a width of a half to three quarters of an inch.

EXPERIMENTS WITH FLUID INSECTICIDES.

In my first report, the twelfth of this office, published in 1883, is a description of the first attempts made to destroy chinch-bugs by means of kerosene mixtures. In the operation there reported, nineteen experiments were made, mainly with emulsions varying in strength from two and a half to six and two thirds per cent. of kerosene, but partly with mechanical mixtures of the crudest kind.

These insecticide fluids were sprinkled upon infested hills of corn during the last days of July, partly transplanted hills which had been removed to my office laboratory and partly hills in the field isolated by surrounding them with barriers of boards and coal-tar impassable to insects on foot. Proper checks were kept in all cases of hills treated precisely like those under experiment except that plain water was substituted for the fluid insecticides. A single additional experiment was made with strong soap-suds to which no kerosene had been added.

The general result of a single application of any of these mixtures was the destruction of about eighty per cent. of the bugs on the corn at the time, the remaining twenty per cent. being either protected by their position from contact with the insecticides or reviving after a time without noticeable injury. Most of the escaping specimens were apparently on the ground under clods of earth when the corn was treated.

Frequent use has since been made of the kerosene mixtures in field experiments by ourselves and by other entomologists, partic-

ularly for the destruction of chinch-bugs accumulating on the outer rows of corn as they move into the fields from wheat or oats at harvest-time. This insecticide method, however, is mainly useful as an adjunct to the barrier method already described.

With a view to testing this operation on a comparatively large scale, I instructed Mr. E. P. Taylor, in charge of my field operations against the chinch-bug in 1904, to prepare and apply kerosene emulsion in the field wherever necessary and practicable in his operations, to keep an account of labor required and the cost of materials, and to observe critically and report the effects of the treatment upon both insects and plants. Experiments of this kind were made in early July of that year with both kerosene emulsion and whale-oil soap.

In the absence of a mixing pump, the kerosene and soap-suds, two parts of the first to one of the second, were thoroughly mixed by a simple violent beating with a stick for about five minutes, the vessels containing the fluids being covered with a cloth to prevent spattering. Emulsions so prepared, although doubtless not so perfect as could be made with a pump, were in every way sufficient for the purpose, standing for at least two hours without any appearance of a separation of the oil and water, and doing no damage whatever to the corn if diluted to contain four per cent. of kerosene. If more than this proportion of the oil were used, injury to the plant was likely to result, especially if the upper leaves were treated.

Details of Field Experiments.—At Fairman, July 4, one fifth of an acre of corn was sprayed with a kerosene emulsion prepared as above and diluted to contain four per cent. of kerosene. No apparatus was used in making the application, but the fluid was simply flirted upon the corn by hand. Ten gallons of the mixture were used in this treatment, equivalent to about a barrel (fifty gallons) per acre, or approximately one and two thirds ounces per hill. The amount of kerosene in a four per cent. mixture used at this rate would be two gallons per acre of corn treated.

Twenty-four hours later none of the plants showed signs of injury, and great numbers of the bugs were dead upon the ground and in the cups at the bases of the leaves. Living chinch-bugs enough remained in this part of the field to extend their attack gradually inwards, until by July 9, five days after treatment, they were to be found in small numbers ten rods beyond the area infested at first. The number remaining, however, was economically insignificant, since no injury to the corn could have resulted.

A second treatment was applied July 12 to this whole area, now about three fourths of an acre in all, twenty-four gallons of the

mixture being used. A part of the corn was now about two and a half feet high, and the chinch-bugs were mainly behind the leaf-sheaths or within the conical cavity at the tip of the plant. The kerosene mixture was applied in part by hand as before, and in part by pouring from a common sprinkling can, but the former method was found the more rapid and also the more economical of material.

As shown by examination the following day, not a plant was injured by this treatment, and only a few bugs were left alive, mainly on plants with leaves so rolled and curled as to protect the bugs within them. A careful count was made of all the bugs, living and dead, found upon ten average hills, including those on the ground about the bases of the plants, with the result that eighty-eight per cent. of all found were dead. An additional treatment was given to the corn still infested, and July 24 the owner of the field, after a careful examination, found an average of twenty to twenty-five living bugs per hill. The corn was at this time beginning to tassel. The same treatment, would, of course, have destroyed any number of chinch-bugs with which the corn might have been infested. As the three quarters of an acre invaded by the bugs was part of a forty-acre field much of which would have been infested and injured if this section had not been promptly dealt with, the result of the treatment was much greater than the protection of the corn actually covered by it. At the rate at which this treatment was applied it would take two hours to treat an acre, or an average of five acres per day.

At Odin, experiments were made July 6 with solutions and mixtures of various strengths to test the effect upon both insects and corn. The plants were young—only about six inches high—and the liquid was thrown upon them by hand, care usually being taken, however, to avoid filling the cavity at the tip of the plant. The emulsions were made by beating, as before, the kerosene being heated before adding it to the soap solution.

Kerosene emulsion was applied in dilutions varying from four to ten per cent. of kerosene, and whale-oil soap was used in solutions varying from an eighth of a pound to two pounds to the gallon of water. With a four per cent. kerosene emulsion applied in a way to drench the entire plant and fill the cavity within the terminal tuft of leaves, no injury whatever was done to the corn, and the chinch-bugs were nearly all killed. A similar treatment with a five per cent. emulsion, however, was injurious to the plants. Some leaves were wilted at the base the following day, and seventeen out of the thirty plants treated were finally killed. Still more serious injury of course followed the use of the stronger mixtures.

Whale-oil soap dissolved by boiling at the rate of a third of a pound to the gallon of water proved too weak to destroy more than a comparatively small percentage of the bugs. With a half-pound to the gallon, the bugs reached by the liquid were practically all destroyed, and none of the plants were killed except where the terminal cavity in the so-called heart was filled, in which case the concentration of the solution due to the gradual evaporation of the fluid caused the leaves to wilt and destroyed the plant. Three quarters of a pound to the gallon was perhaps a little more effective as an insecticide, but somewhat more dangerous to the plant. A few plants which were carefully treated were seen six days afterward to have been injured slightly, the injured leaves rolling up or growing in distorted forms. Where as much as a pound and a half per gallon was used nearly all the plants were killed, and two pounds per gallon was fatal to every one.

From the above it appears that a solution of whale-oil soap—one half pound to the gallon—is a safe and successful insecticide for corn-field use. As its cost, however, is about three times that of the four per cent. kerosene emulsion, it is scarcely to be recommended except on the score of occasional convenience. Where a barrel of the four per cent. emulsion costs thirty-four cents, a barrel of a half-pound solution of whale-oil soap will cost $1.12.

Such fluid insecticides may best be applied during the cooler parts of the day, since the plant is less subject to injury then and the bugs feed more thoroughly. Enough of the liquid must be applied to wet the insects thoroughly, since otherwise they are likely to recover from its effects. For a complete operation, two and even three applications may sometimes be necessary.

EXPERIMENTS WITH THE GASOLINE BLAST-LAMP.

The use of the ordinary plumber's torch, or some modification of it, for the destruction of injurious insects on their food plants seems to have occurred independently to several persons during the last few years, and to have been tried with some care as a practical measure by several disinterested men competent to make exact observations and to report results without bias or prejudice.

Mr. S. A. McHenry, recently superintendent of one of the horticultural substations of the Texas Agricultural Experiment Station, is reported to have used it for several years against the harlequin cabbage-bug, and Professor J. M. Stedman, of the Missouri Experiment Station, has also used it against the same insect. Professor R. H. Pettit, of the Michigan Agricultural College, tried it on the

San Jose scale as far back as 1897, publishing in the Bulletin of the Michigan Experiment Station the earliest report of an exact experiment with it which I have seen; and Professor Craig, of the Horticultural Department of Cornell University, has also tried it on this scale. Professor E. D. Sanderson, formerly of the Texas Agricultural College and Experiment Station, has used a form of it on the cotton boll-weevil. Professor Thomas B. Symons, of the Maryland Agricultural College and Experiment Station, used it experimentally on the San Jose scale, and on beetles infesting the aster. Professor J. L. Phillips, State Entomologist of Virginia, has also tested it on the San Jose scale with unusual thoroughness; Professor F. M. Webster, Entomologist of the Ohio Agricultural Experiment Station, had it tried four years ago by an assistant, Mr. C. W. Mally (now Government Entomologist in Cape Colony, South Africa), on a variety of insects, including the chinch-bug; and two of my own assistants, Mr. E. S. G. Titus and Mr. G. I. Reeves, have used it on scale insects, caterpillars, and moths; have tested it for the destruction of fungus parasites of the green leaf; and have determined its effects on various kinds of vegetation when applied in a way to kill the insect enemies of the plant. Most of these experiments are unpublished, but their results have been generously placed at my disposal for use in this brief discussion.

Although no one of those here mentioned has made a trial of the gasoline torch for all the insecticide and fungicide purposes which it might possibly serve, the total results have a considerable value as showing definitely some things which can and some things which can not be done with it, and as indicating the directions in which further trials may be had if indeed it appears that further trial is necessary or worth while. Some variation and conflict in the reports of some of these experiments are evidently due to differences in the apparatus used, this varying from a poorly constructed and feeble torch, made in Illinois especially for insecticide work, to a large and powerful blast-lamp, used in Texas for burning the thorns off prickly pears.

The idea that exposed insects of small size may be quickly destroyed by the sudden and brief application of a blast of very hot air, or even of actual flame, without injury to the plant on which they may be feeding at the time, strikes one favorably at first thought; and there seems, in advance, to be no obvious reason why this method may not have a considerable practical value. The living animal is often more sensitive to sudden heat exposures than the living plant, and the margin between exposures fatal to each may in some cases be so wide as to make this method fairly safe in

ordinary practice. The smaller the insect, of course the more quickly it may be killed by the hot blast; and the better the living tissue of the plant is protected by a lifeless cuticle or a layer of bark, the longer it may be exposed to this blast without being heated to the point of injury. Bark-lice on trees and shrubs are thus favorable objects for experiment; but where thick-bodied insects, like caterpillars and large beetles or bugs, themselves covered with a dense crust of lifeless cuticle, are feeding on the young green leaf, the margin of safety is greatly narrowed and may wholly disappear. The practical utility of this method of destroying insects in any case, evidently depends on the existence and extent of this margin of safety.

The gasoline blast may, in fact, be used to kill any insect on any plant. The time and method of use necessary to kill the insect will vary widely for different kinds of insects and for the different states and stages of each kind; and the time and method of use sufficient to injure various kinds of plants will likewise differ widely according to the kinds and condition of the plants themselves. The actual effect of the blast on either insect or plant will also vary enormously according to small details of the method by which it is applied. They will vary, first, with variations in the pressure, which determines the extent and heat of the flame; second, with the distance from the object at which the torch is held; third, with the rate of movement at which the flame is passed over the surface treated; fourth, with the temperature at the time and the amount and direction of the wind; fifth, with the direction of the blast, whether perpendicular or oblique to the surface; and sixth (not to specify further), with the steadiness with which the flame is applied to a given surface, whether held at one point for a definite time or swayed back and forth over a considerable surface for a variable number of times.

To determine the effect of all these different classes of variations with sufficient exactness for practical guidance, and then to combine all the various results of this inquiry with each other in a way to form a system of practice which can be accurately described and safely recommended for general use, is a task which no intelligent investigator would enter upon lightly, or without such preliminary tests as would enable him to judge whether any important result was likely to come from more exact and extensive experiments. The observations here reported are all in the nature of such preliminary tests, made by different persons, each for his own satisfaction, on different objects and in different parts of the country. They are practical tests rather than complete scientific experiments, and

their value is hence suggestive rather than final. Those which have to do with the San Jose scale, the harlequin cabbage-bug, and the cotton boll-weevil are perhaps of the greatest interest, and will be given first.

The San Jose Scale.—In the fall of 1897, Professor Pettit, of Michigan, had five parallel burners fitted to an ordinary plumber's blast-lamp in such a way that a flame about ten inches wide could be directed against the surface of a tree, and several trials of this apparatus were made during the following winter on peach- and pear-trees badly infested with the San Jose scale. "The heat produced by this lamp," he says, "is very intense, and great care must be observed not to allow the flame to remain at any one point long enough to injure the tree. The best results were obtained when the flame was steadily moved so that it covered a space of a yard in length in from five to ten seconds. The results seemed to show that the blast will kill the scale-insects with little or no injury to the tree. The trees were scorched in places where the flame had moved too slowly, and the care necessary to avoid the scorching appears to be the most serious drawback to the use of the blast lamp. In careless hands much injury may be done in a very short time, while the skilful handling necessary for success would be rather expensive under ordinary circumstances. Good judgment must be exercised always, and the rapidity and effectiveness of the work will be much modified by the temperature of the air, the direction and force of the wind, the age of the trees, and the thickness of the incrusting scales." Referring to these statements in a recent letter, Professor Pettit writes that he intended that the lamp should be used only in connection with a spray, for burning off or loosening the outer layers of a crust of scales so that a fluid insecticide might penetrate to those beneath. "I now realize," he says, "that the same effects may be obtained much more cheaply in other ways."

By Professor Craig, of Cornell University, a torch much advertised for the destruction of insects was used May 19, 1903, against the San Jose scale on the apple, medlar, buffalo-berry, and dog-wood. Different branches were flamed in various ways to ascertain the time necessary to kill the scale and to determine the minimum exposure to the flame of the torch which would kill the cambium layer of the tree or shrub. In respect to time of exposure three methods of treatment were used: passing the flame so rapidly over the surface that it merely touched each point for an instant; moving it at the rate of one foot per second; and holding it stationary on the infested spot long enough to count one. The scales were reported to have been killed in every case save one, in which a twig of dogwood had been

very rapidly flamed. "The general results," writes Professor Slingerland "were summarized as follows: First, the torch is impracticable for large trees of apple, plum, pear, peach, or cherry, because of the amount of time required to flame the whole tree. It would take a man several hours thus to go over one large tree; second, there is great danger of injuring buds or the cambium layer on thin-barked trees; third, the torch might be used on small nursery stock or ornamental shrubs by an experienced operator who knew exactly what time to expose the plant to the flame."

Professor Phillips, of Virginia, made use, against the San Jose scale, in 1903, of a torch sent by the manufacturing company for trial to Professor Alwood, of that state. "March 28, of this year," he says: "I used this gasoline torch on two apple-trees four years of age. These trees were moderately infested with the San Jose scale, and were treated by running the torch over the surface several times. One tree was exposed to the torch about twice as long as the other. This treatment did not appear to injure the trees, neither did it kill a perceptible number of insects.

"I was not satisfied with this trial, however, and detailed a student assistant, Mr. E. F. Cole, to test the torch, which he did August 7. The tree treated was a four-year-old apple, badly crusted with the San Jose scale. As it would be entirely impracticable to use this torch against the San Jose scale during the summer, this treatment was confined almost entirely to the trunks and main branches of this tree, but in treating the tree in this manner, of course a few of the leaves were also reached by the flame. The treatment was so severe that the leaves on the treated portions of the tree were killed at once, and when examined on August 20, portions of the bast tissues of the bark were found injured also. Quite a large number of scale insects were alive at that date.

"Judging from these two tests, I consider that the use of this torch is quite tedious and impracticable, even on small trees. Besides, such a small per cent. of the San Jose scales were destroyed by it, even where the trees were seriously injured by its use, that I do not consider it a practicable remedy."

Professor Symons, of Maryland, writes me that he personally conducted some experiments with the same kind of a torch on different varieties of peach and plum infested by the San Jose scale, but that the results were not at all satisfactory. Although the insects were dead two weeks later on the parts which had been hit by the flame, young scales were crawling about over the surface in considerable numbers, showing that it had been impossible to reach all parts of the tree, especially at the ends of the branches. If used

when the tree was in leaf he could not avoid burning the foliage. As a result of his experiments, Professor Symons concludes that it is impracticable to control the San Jose scale with this torch.

To these observations by experts I may add a note of a trial of the torch made by a practical gardener on some infested trees belonging to J. W. Stanton, of Richview, in this state. By oversight, these trees were sprayed with whale-oil soap before they had been critically examined as to the final effects of the blast on the San Jose scale; but Mr. Stanton writes me that from what he could see of the effects of the treatment at the time, he is of the opinion that it would not be successful on tree fruits. One of my horticultural inspectors, Mr. R. W. Braucher, happened, however, to examine one of these trees after the treatment with the torch and before the application of the whale-oil soap, and found that the bark was scorched in some places, and that in others the scales were still alive.

From the foregoing experiments, it is clear that the gasoline torch has at best only a very limited application in the treatment of trees infested by the San Jose scale. It might be occasionally used to advantage, as suggested by Professor Pettit, to burn off the outer part of an unusually thick crust of scales on the trunk and largest branches of a tree, preliminary to a treatment with the lime-and-sulphur wash. As this insecticide does not penetrate readily to any great depth, it is sometimes necessary to repeat a spraying after a time if the tree is too thickly incrusted. This second spraying might perhaps be omitted if the torch were first used on the crust of scales. It would be the merest folly, however, to think of using it as a substitute for an insecticide spray in the treatment of the San Jose scale, or for any general treatment of orchard trees for any purpose whatever.

This torch was also tried on certain other orchard scales at Urbana during the fall of 1902, but for reasons to be given presently these tests are reported separately farther on.

The Harlequin Cabbage-bug.—The introduction of the use of the gasoline torch against the harlequin cabbage-bug in the South seems to be due to Mr. S. A. McHenry, recently superintendent of one of the substations of the Texas Agricultural Experiment Station. Indeed, Professor Sanderson, when official Entomologist of that state, wrote me that, so far as he knew, Mr. McHenry was the first man to make practical use of the blast torch against insects of any kind. He is said to have used it successfully for several years, as have others in his section of the state, but of late he has made

comparatively little use of it for that purpose because of the amount of work required to go over a cabbage plant with the torch.

Professor J. M. Stedman, of Missouri, writes more confidently of its usefulness against the cabbage-bug, saying, under date of October 28, 1903, "I have not found the gasoline torch of any special value as an insecticide apparatus except in extreme cases when one has a sufficient number of the harlequin cabbage-bugs in his cabbages to cause serious trouble. I have then used this torch to good advantage. One can very readily pass over the cabbages fast enough not to injure them, and at the same time to kill the harlequin bugs. It is not necessary to have the bugs scorched sufficiently to drop at once, as I have found that they will ultimately die if this intense heat has been very rapidly applied."

This cabbage-bug is not widely destructive in this state, although it is continuously present in some parts of southern Illinois, and during one season extended its injuries as far north as Champaign, and was once found in Chicago by Mr. A. Bolter. The reported effectiveness of this torch against this insect suggests the trial of it against other bugs, which cannot be killed with arsenical poisons since they do not eat the solid substance of their food plant but merely suck its sap.

The Cotton Boll-weevil.—The appearance in Texas of the snout-beetle known as the Mexican boll-weevil has caused general and justifiable alarm among the cotton-growers of the South, and the former Texas State Entomologist, Professor Sanderson, has devoted himself to an assiduous study of the insect and has made many experiments for its destruction and control. This is indeed the most important, pressing, and perplexing problem which the economic entomologist now has to deal with in the Southern States. In the course of his work against this insect Profesor Sanderson has tried two forms of the gasoline torch; one, a blast-lamp known as the pear-burner, used in southwestern Texas for burning the thorns off the prickly pear, and the other a torch sent him from Illinois by a dealer who offers and advertises it for sale for the destruction of insects. The latter was found so faulty in construction that it could not be used, and it was consequently returned.

The pear-burner, which generates a much more powerful blast than any of the smaller torches, was tried by Professor Sanderson for burning up the squares of the boll-weevil as they lay upon the ground, but so far, as he writes me October 28 of this year, he has not had sufficient success with it to indicate that it has any value for this purpose.

The only other beetles on which it has been tested by any of my correspondents are certain unspecified species found on aster by Professor Symons, of Maryland. "In this case," he says, "it was effective in killing the beetles, but one has to be so extremely careful not to hurt the flowers that I would hardly recommend it for practical use."

Experiments at Urbana.—In response to my request, made August 5, 1902, to the inventor and patentee of a modified form of the gasoline torch intended especially for insecticide work, one of his instruments was sent me with directions for its use, and was at once put into the hands of my most experienced field assistant, Mr. E. S. G. Titus who, with the aid of another assistant, Mr. George I. Reeves (both now assistants to the United States Entomologist), tried it at various times during the following two months on such kinds of injurious insects as could be found in any number at Urbana at that time of the year. It was further tried on a fungus parasite of the lilac leaf, and on various kinds of vegetation to determine the effect on the plants of an exposure sufficient to kill the insects infesting them. Although sent me expressly for experimental purposes, this instrument proved to be relatively so weak in action that its use by us should probably be regarded as a test of the value of this kind of a torch rather than that of the torch method in general; and it is on this account that I have kept our own statements separate from those made to me by others, most of whom seem to have worked with a more efficient apparatus.

The results of our various trials are here given as reported to me by Mr. Titus at the close of his series of experiments, about October 20.

"The torch is simply an ordinary 'plumber's torch' fitted with a two-gallon gasoline tank and a three-foot piece of rubber tubing. A short iron discharge-pipe connects the rubber tubing with the torch.

"Filled the tank about half full of gasoline according to directions. The valve in this pump was of leather and by no means circular in outline, and it was at first rather hard to secure even pumping pressure. The connections were all very dry and needed soaking. After an hour or so of work, cleaning the discharge-pipe and burner, we were able to light the latter and get a flame.

"Under the heaviest pressure obtainable—sufficient to force air bubbles from the pump valve and at the cut-off in the base of the pump—the flame was tried at varying distances. At fifteen inches from the burner the heat was scarcely sufficient to singe the hair from the hand, but a little closer, ten to twelve inches distant,

it would singe. The burner was used when running at full force. The effects were about as follows, examinations being made at several days' intervals:—

"The trunk and smaller limbs of an apple-tree were thoroughly treated. This tree was badly infested with Forbes and scurfy scales, and also had on it considerable woolly aphis. The last-mentioned insects were killed where they were completely burned off the limb; but where only the woolly covering was burned off, and the insect not actually caused to drop, there was little apparent injury. The Forbes scale appears not to have been injured, except the young not yet old enough to form a scale. The scurfy scale was not injured. The smaller limbs were sufficiently treated to cause the bark to blister in spots, without having any apparent effect on mature scales of either kind.

"I have tried the burner under ordinary pressure at different times against various other insects and foliage. A colony of fall web-worms in a box-elder tree was treated, and a number of worms that fell were placed in a cage in the insectary. These were given plenty of fresh food, and did not appear to be inconvenienced by the lack of hairs on their bodies. They grew, and some of them pupated. Most of the remainder were parasitized, and the few that died were full grown at death. The parasites emerged in due time and were preserved.

"Arctian caterpillars (woolly bears) treated to the full force of the burner for ten to fifteen seconds, or even longer, had the hair thoroughly singed from their bodies, and some were blistered. The majority of these finished their growth and pupated. I could see no greater mortality among them than ordinarily occurs with this species under insectary conditions. Several cabbage-worms were treated until they rolled from the leaves. Most of these were not permanently injured, and those that died were burned so badly that the outer skin was broken. To produce this effect upon a caterpillar it must be treated with a direct blaze long enough to cause the leaves to curl and blacken on the plants.

"Meadow moths (*Crambus*) flying about in the grass were singed with the flame. Some of these would fly through the flame so close to the burner that the hair on one's hand would be quickly singed off, but they were usually uninjured by this experience. To kill one of these moths it had to be followed with the flame until some parts were burned sufficiently to cause it to fall, when it could of course be easily disposed of.

"Lilac leaves badly infested with mildew were thoroughly treated, the burner being held at varying distances and acting for

varying periods of time. The mildew does not seem to have been affected where the leaves were not injured, and was rarely affected where the leaves were burned sufficiently to cause them to curl and later to wither. Leaves that were treated to the flame for three seconds dropped off. Other leaves treated one second remained on the bush and were not perceptibly injured. Between these two times (which really represent flashing the burner over the surface and holding it there for an instant) the leaves show varying injuries. At first the mildew appeared to have been burned off, but specimens which had been thoroughly treated and left in the insectary were again covered with the mildew in five days.

"Elm, Osage orange, box-elder, apple, cherry, plum, grasses, nasturtiums, cabbage, pine, cedar, *Amorpha,* walnut, rose-bushes, peach, and several other trees and ornamental shrubs have been treated at various times: I find that when the flame is held close to the foliage for a few seconds this is visibly injured. If held a short distance away the injury is not so great, but usually shows after a few days by the blackening of the leaf or by the browning and curling of the edges. Often leaves so treated will drop off.

"To sum up: The use of sufficient heat to destroy effectually insect larvæ of the kinds we treated, will injure the foliage and often the twigs."

Mention may be made of a trial of the torch by Mr. Mally, in Ohio in 1898, the details of which can not now be given because the record is not accessible. This torch, obtained from Illinois, was put into Mr. Mally's hands by Professor F. M. Webster, with instructions to give it a thorough test. It was taken by Mr. Mally on one of his field trips, used on a variety of insects, including the chinch-bug, and returned with the general report that it was unsatisfactory for its purpose.

USE OF THE GASOLINE TORCH AGAINST THE CHINCH-BUG.

Notwithstanding the generally unfavorable character of the statements made to me concerning this torch by those best able to judge of its value, it seems that it may have a field of usefulness for the destruction of certain kinds of injurious insects. Thinking that it might profitably be tried in comparison with other aids to the trap and barrier method for the destruction of chinch-bugs as they come out of small grain in midsummer, I provided for a series of field trials with a first-class torch, in connection with other experiments on the chinch-bug made during the summer of 1904. To make sure of having a good example of this form of blast-lamp, one

was bought from the manufacturer in person, who was kind enough to give careful instructions and to illustrate personally its use in the field.

Two miles south of Carbondale was a field of forty acres of corn adjoining wheat infested by chinch-bugs, which had almost completely destroyed the corn on an area two hundred and twenty yards long and seventy yards in depth. Only a few scattering hills remained on this strip, and a good deal of this was lying almost flat on the ground. Farther within the field the corn was only moderately infested, but was of course still liable to serious injury by the invading host. July 30, when this experiment began, most of the bugs had developed wings, though many were still to be found in all stages from the very young to the lately transformed adult.

The lamp was first used on fallen hills thickly covered with the bugs, many of which, however, were concealed within leaves closely rolled for their entire length. When the blast of flame was turned upon the corn, many bugs exposed on the surface of the plants fell to the ground, where they could easily be killed by following them with the flame. Many others, however, would not leave their shelter among the leaves, and these were left uninjured.

Where the field was only moderately infested, scattered adults and clusters of them exposed to the flame dropped to the ground at once, where they could be quickly destroyed; but many dropped from the side of the hill farthest from the torch, where they could not be reached until the operator returned down the other side of the row, as only one side of the hill could be treated at once. Indeed, for a satisfactory application of this method it would be necessary that two men should take a row together, one on each side, operating against each hill simultaneously. Even this would not wholly prevent the premature escape of the bugs, as many fell from the corn two or three hills in advance of the roaring blast and hurried away in an effort to escape. Those which remained secreted behind the ensheathing bases of the leaves were also, of course, protected from injury. In this respect the blast-lamp proved less efficient than the kerosene emulsion, since the latter was especially useful in reaching the accumulations of chinch-bugs hidden behind the leaves.

For a more accurate test of the effect of the hot blast ten cages were arranged in such a way that the bugs could be treated within them and held captive under normal conditions for observation afterwards. In one of these cages two hundred and fifty chinch-bugs, mainly adults, were flamed with the exit of the blast held for one second an inch from the bugs, the pressure having been pumped up about to a maximum by two hundred strokes of the piston. The

following day eighty per cent. of the bugs were dead, together with several adult blister-beetles (*Epicauta marginata*) and Colorado potato-beetles treated at the same time.

In another test like the preceding, except that the bugs were exposed to the blast for two seconds, eighty per cent. were dead the following day. A third experiment duplicated the first with a result to kill eighty-five per cent. of the bugs. In a fourth cage the flame was held for a second two inches from the bugs, and the following day seventy-five per cent. of the two hundred and fifty treated were found to have been killed. At a distance of four inches the flame killed but ten per cent., the remainder crawling about, apparently uninjured, twenty-four hours later. An adult potato-beetle and two larvæ of the same, a common cabbage-worm, and a caterpillar of the cabbage Plusia were likewise uninjured by this treatment. In another experiment it was shown that if the burner were held three seconds at a distance of four inches from the insects, only ten per cent. of the chinch-bugs were killed.

A thousand chinch-bugs were next exposed to a gentle blast of the gasoline flame until they were all unable to crawl. On the following day about fifty of them were still able to move, although the legs and other appendages of some of these were scorched.

In order to ascertain whether the bugs might die from the after-effects of the blast, a thousand specimens in another cage were subjected to an extreme scorching heat without killing them at the time. On the following day at least half of them crawled away, evidently uninjured. Another lot of a thousand were flamed until a third were killed outright, the remainder being rapidly flamed several times but left able to crawl away. On the following day at least two thirds of the bugs were alive. From these experiments it appears that bugs not killed at the time of treatment do not ordinarily die thereafter. A lot of two thousand chinch-bugs or more, collected from corn and confined in a similar cage, which were kept as a check during the course of these experiments, lived with less than one per cent. of loss, and these were probably injured in collecting.

To determine the resisting power of the corn to the hot blast of the gasoline torch several plats, equally infested and all in one field, were treated variously. The flame was moved over the plants sometimes quickly, sometimes slowly, and was sometimes held close to the leaves, sometimes at a greater distance. In this experiment the unit was a plat of a hundred hills of corn, which averaged three feet high at the time. All plats were treated in the afternoon of July 30, the weather being clear and hot, with a little wind. The lamp was used at a high pressure, produced by two hundred suc-

cessive strokes of the pump. The heat was sufficient to scorch the hairs from the back of the hand at twelve inches from the burner, and to burn in two in thirty seconds a stalk of corn held four inches from the nozzle.

In the first plat the flame was passed steadily upward for a foot along the stalk at the rate of about two feet per second, this flaming process being four times repeated for each side of the hill with the nozzle held an inch or less from the plant. Each plant was thus exposed to the blast for four seconds in all, a half a second each time. Two days later some of the bugs were dead, but many were still alive, and many stalks of corn were seriously injured, scarcely a hill in the plat having wholly escaped scorching. In some hills the large leaves were burned, and in nearly all the lowest leaves were visibly scorched.

This experiment was repeated on another plat except that the tube was held about four inches from the plants. Two days later the corn was less injured than in plat one, but nearly all was scorched more or less, especially the upper leaves. Some of the bugs were still alive, probably those which fell to the ground and escaped and those secluded beneath the sheaths of the leaves.

In another plat the treatment was varied by flaming the bugs at the base of the plant as they fell upon the ground, using on an average two seconds additional for each hill. The torch was handled about as in the first experiment, and the plants were similarly injured. The hardened cuticle at the base of the stalk was less likely to be scorched than the green and tender leaves. The bugs were nearly all destroyed on this plant, although a few were still alive the following day.

By other experiments it was found that by two or three treatments, separated by intervals sufficient to allow the escaping bugs to collect again, the corn might be almost completely cleared of bugs, but, unfortunately, without the most painstaking care injury to the plants was such as to make this form of treatment quite inadmissible.

The cost of these operations was considerably less than the corresponding treatment with kerosene emulsion. The time required was practically the same, but the cost per acre was thirty-four cents for the emulsion and fifteen cents for the gasoline.

It was Mr. Taylor's judgment that two treatments with a four per cent. emulsion would have about the same effect upon the bugs as three applications of the torch, but the latter is more convenient to use, requiring no previous preparation of the fluid and no hauling of water to the field. The risk of injury to the corn is of course

much greater with the torch—especially in the hands of unskilled or careless workmen. The price of $10 charged for the blast-lamp would determine the choice of many, since apparatus may be wholly dispensed with in the preparation and application of the kerosene emulsion.

There is an evident use for the gasoline torch in the destruction of bugs collecting either in the dusty furrow or along the coal-tar line, where these are used as barriers against the movement of the chinch-bugs from small grain to corn. By directing the hot blast against the insects trapped in the furrow or collecting along the tar line on the ground, these could be rapidly killed at small expense, and the post-hole traps might thus be dispensed with. Care would be necessary, however, to prevent the burning or drying of the tar by the flame.

It also seems quite probable that a fine spray of pure kerosene, or even of crude petroleum, might be used to good advantage for the destruction of the chinch-bugs on the ground, and perhaps at less expense. On the coal-tar line the kerosene might be preferred because it would tend to soften the tar and lengthen the period of its efficiency as a barrier, and could not dry and harden it as would the flame. Opportunity was wanting last season for experiment covering these last suggested points, and they must consequently be tested at some other time.

At a later date the blast-lamp was used in the potato field to destroy the adults and larvæ of the common potato-beetle. For this operation it was found entirely impracticable. The insects could of course be killed, but at an expense of about fifteen hours of labor per acre.

GENERAL SUMMARY.

These experiments may be considered as a test of the efficiency of barriers constructed to arrest the movement of chinch-bugs in passing from small grain to corn at harvest-time, under conditions unfavorable to success, that is, when the chinch-bugs were not so numerous as rapidly to destroy the wheat—compelling their migration en masse—and when the weather was neither extremely hot nor very dry. The spring and early summer of 1904 proved to be unusually wet, and chinch-bugs consequently were not generally abundant enough to threaten any great injury to corn. The weather also prevented the use of the dusty furrow, most commonly resorted to as a barrier to the movements of chinch-bugs, and compelled a reliance on the coal-tar line with post-hole traps instead. So far as the season permitted a real test of the operation, it was completely

effective for the protection of corn, and there is no doubt that it would have been equally so if chinch-bugs had been ten or a hundred times as numerous.

A partial failure of the experiment due to the character of the weather of the season did not diminish its value as a means of determining the cost of an effective operation on the scale of actual farm practice. It was demonstrated that the coal-tar strip may be laid down and maintained for four weeks—the maximum period necessary—at a cost of $22 a mile, with the effect to trap all bugs approaching the line, where they may be readily and rapidly killed. The average cost of making a dusty furrow or ditch sufficient to arrest and trap all chinch-bugs attempting to cross it was approximately three cents a rod, or $10 a mile, for labor only, no materials being required. This furrow can not be used, however, except in dry hot weather.

Various methods of preparing the ground for the coal-tar line were used in comparison. One of the most satisfactory methods was that of plowing a back furrow in the stubble near the edge of the field, and packing this with a roller or beating it flat and hard with spades. A strip of sod may be prepared to receive the line by scraping away the grassy surface with an ordinary farm scraper, afterwards leveling and smoothing it carefully with a shovel or hoe.

A kerosene emulsion prepared by mixing two parts of kerosene and one of soap-suds by violently beating with a stick for about five minutes, and diluting to contain four per cent. of kerosene, was found efficient for the destruction of all the chinch-bugs touched by it, and was successfully used for clearing rows of corn along the borders of a field which had become infested for lack of effective barriers. Stronger kerosene mixtures made in this way commonly proved injurious to the plant. A barrel of diluted emulsion costs about thirty-four cents. It was applied to the corn by hand at an average rate of a barrel an acre—five acres per day for each man. A solution of whale-oil soap, one half pound to the gallon of water, proved to be a safe and sufficient insecticide for corn-field use. Its cost was $1.12 a barrel.

The gasoline blast-lamp, tested on a great variety of insects, was found to be only occasionally useful. By two or three successive treatments separated by intervals sufficient to allow the chinch-bugs which escape to collect upon the plant, badly infested corn might be almost completely cleared of bugs, but serious injury to the corn itself was almost certain unless the most painstaking care was used. The cost of material is less than that of kerosene, amounting to only about fifteen cents an acre for each treatment with the

former and thirty-four cents for the latter. Three applications with the torch were about equal to two treatments with the kerosene emulsion, the first being most convenient to use but also most dangerous to the plant. It is suggested that this gasoline torch may be found a convenient apparatus for destroying chinch-bugs collecting either in the dusty furrow or along the coal-tar line, when these are used as barriers.