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BULLETIN No. 108

SPRAYING APPLES FOR THE PLUM-CURCULIO

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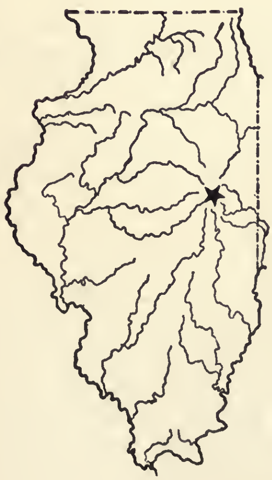

URBANA, MAY, 1906

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SPRAYING APPLES FOR THE PLUM-CURCULIO.

It has been known for more than a hundred years that the apple was subject to injury by the plum-curculio, but as this injury has been commonly reckoned less important than that done by the codling-moth, the matter has received, of late, comparatively little attention until within the last six or seven years. Since the discrimination of different market grades of apples has been generally introduced—a grading based not only upon size and soundness, but also upon superficial appearance—the slight surface injuries done by the new generation of the plum-curculio, both in laying the eggs and in feeding on the fruit, have acquired a great importance. The consequence of a noticeable injury of this sort, although affecting but little, and in many cases scarcely at all, the edible quality of the apple so injured, is to reduce its selling value from No. 1 grade to No. 2, the actual profits of the crop disappearing in this process. These facts having been repeatedly brought to my knowledge by Illinois horticulturists, I undertook to work out the causes of these surface blemishes in general, and to demonstrate more accurately than has hitherto been done means of preventing them by a destruction of the curculios themselves. Indeed, the importance of this investigation has grown upon me as it has become evident that these small superficial injuries very often give entrance through the skin of the apple to bacteria and to fungus spores of various kinds, causing rots and blights of the fruit which might be largely prevented by a timely destruction of the insects.

Some Earlier Experiments.

The first exact experiments with insecticides for the protection of apples against the plum-curculio were those made at my office in 1885, on a small orchard hired for the purpose near Urbana, Ill., the results of which were published in one of my reports*, and in the Transactions of the Illinois State Horticultural Society for that year. In this experiment, which was made primarily to test insecticide measures for the destruction of the codling-moth, the effect on cur-

*Misc. Essays on Econom. Ent., 1886, pp. 26-45.

culio injuries was likewise ascertained. Eight trees were used, 4 of them being sprayed and 4 reserved as checks. Two of the trees were treated with Paris green, 1 with London purple, and 1 with lime. All applications were made eight times, beginning the 9th of June and continuing until September 3.

All the apples borne by these trees, 16,529 in number, both those which fell and those which remained on the tree, were examined one by one, and the results were tabulated for comparison. Although this was my first work with orchard insecticides, and the application was doubtless not made as thoroughly as would now be done, the general result of the work with Paris green was to save uninjured on the trees 56 per cent. of the apples which would otherwise have been injured by curculios—a percentage less than was to have been expected in orchard practice because, as noted at the time, there were other bearing trees in the orchard, from which those treated unquestionably became reinfested to some extent. As apples were not graded at that time, no attempt was made to distinguish differences in the crop borne by trees sprayed and those left unsprayed as checks, beyond the mere number of the injured and uninjured apples; but results which I shall presently describe make it certain that the actual percentage of benefit would have been much greater than that indicated by these figures if I had also taken account of differences in size and quality of the fruit.

Because of repeated reports of general and important, though slight, surface injuries to apples by insects in summer and fall, I sent an assistant, Mr. E. S. G. Titus, through southern Illinois in June and July, 1901, to observe and collect examples of these injuries, and such insects as might be held responsible for them. Quantities of blemished fruit were sent to the office for careful study, and as a means of rearing any insects which it might contain.

From this investigation it appeared that much the greater part of the injury complained of was due to the plum-curculio, and that the control of this insect would virtually protect the apple—a fact reported to the Illinois State Horticultural Society for that year, and published in its Transactions (p. 148).

Pursuing the subject further, I read at the meeting of this same Society in 1902 an article* prepared by Mr. Titus, the greater part of which was given to the work of the plum-curculio in the apple orchard. In addition to a report of many careful observations, an important suggestion was made in this paper to the effect that, since injury to the fruit was least in well-cultivated orchards, cultivation

*"Insects, other than the Codling-moth, Injurious to the Fruit of the Apple," by E. S. G. Titus. Trans. Ill. State Hort. Soc., Vol. 36, pp. 158-162.

at a time when the bulk of the curculios are in the ground passing through their transformations might have the effect to diminish their number by killing them in the pupa state. For this purpose, it was said, a midsummer plowing would be necessary, followed by harrowing to break up the clods and expose the pupæ more thoroughly to the weather. The prompt destruction of the fallen fruit and spraying of the trees with Paris green were also prominently mentioned.

The following year, in a paper* on "The Curculio and the Apple" presented to the State Horticultural Society, Professor C. S. Crandall, of the Horticultural Department of the Illinois Experiment Station, gave the results of a season's work, experimental and entomological, in an orchard in the western part of the state. This article reports the writer's observations, and those of his assistant, Mr. James R. Shinn, with respect to many points of interest in the life history and habits of the plum- and the apple-curculios, their numbers in the apple orchard, and their injuries to the apple, together with the outcome of certain spraying experiments made as a test of the insecticide method of controlling their injuries. Entomologists will be especially interested in the precise details of the life history and in minor particulars concerning the habits of these species.

The spraying operation was reported as unsuccessful, even thirteen to sixteen applications of Paris green, extending from May 15 to August 15, seeming virtually without effect. As only 120 trees were used in these experiments out of an orchard of one hundred and twenty-five acres, and as these experimental trees were divided into plats of 10 trees each, it is evident that the sprayed trees were subject to continued invasion from the surrounding orchard, sufficient, possibly, to obliterate the results of the treatment. A suggestion which I have already mentioned—that of plowing and harrowing infested orchards in midsummer to destroy the pupæ in the earth—is here reinforced with numerous exact observations as to the time of pupation, and the depth to which the curculio larvæ penetrate for their pupal transformations.

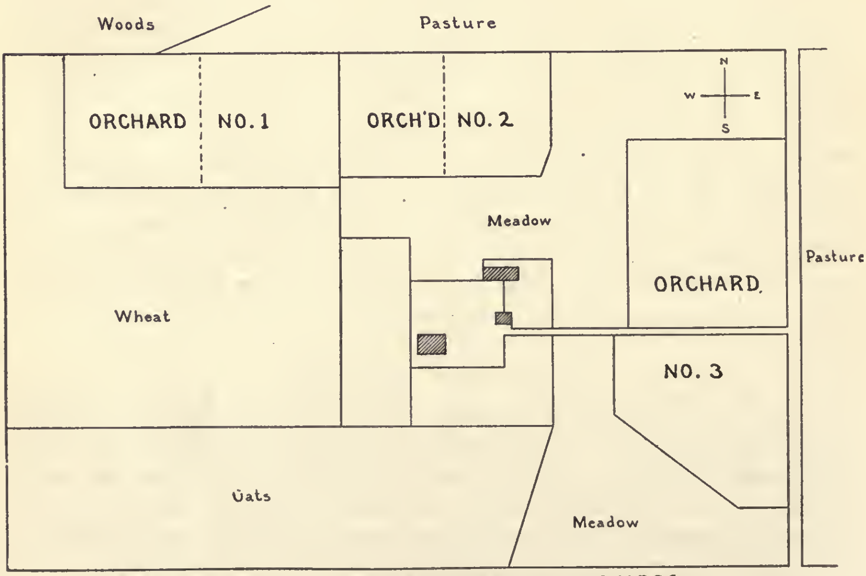
EXPERIMENTS OF 1904.

Owing to the unfavorable outcome of these experiments of 1903 for the control of curculio injuries by the use of insecticides, it became important that measures should be taken to test anew the usefulness of the arsenical sprays, especially as these are necessary to any program of fairly complete protection to the crop of apples on

*Trans. Ill. State Hort. Society, Vol. 37, pp. 176-189.

the trees. Destruction of windfalls and midsummer plowing have the disadvantage that they lock the stable after one of the horses, at least, is stolen, since they can at most prevent only injuries by the new brood of curculios appearing after midsummer. In the absence of poison sprays, an orchard freed of curculios in midsummer —if this is possible—by plowing and harrowing, would be liable to invasion and serious injury later in the season by insects entering it from outside, and would also be exposed to injuries in the spring and early summer of the following year. With these facts in mind, I undertook, in 1904, a field experiment in southern Illinois intended to test the practical value of an arsenical poison directed immediately against the plum-curculio, with the understanding that similar experiments were to be carried on by the Horticultural Department of the State Experiment Station in another part of the state. My experiment was placed in charge of my field assistant, Mr. E. P. Taylor, and this report is based on his field notes and specimens.

The farm selected, after an examination of some twenty-five fruit farms in southern Illinois, contained three small orchards aggregating eighteen acres. It was situated two miles south of Carbondale, in Jackson county. These orchards were chosen partly because of the considerable crop which they bore—an unusual thing that year—and also because the separation of the varieties with which they were planted, enabled us to make, in most cases, check and experimental plots of the same variety.



SITE AND SURROUNDINGS OF EXPERIMENTAL ORCHARDS

The insecticide used was a compound of arsenate of soda and acetate of lead commonly known as the arsenate of lead. It was made by dissolving 12½ ounces of the acetate of lead and 5 ounces of arsenate of soda in separate vessels, and pouring the two solutions, one after the other, into a barrel with 50 gallons of water. Two barrels were placed in the wagon at once, each with a No. 2 Morrill and Morley spray pump carrying two lines of hose about twenty-five feet long, furnished with twelve-foot extension poles fitted with double Vermorel nozzles.

In spraying, as high a pressure was used as could be kept up by hand; and a fine mist of the spray was forced into the trees from every side, care being taken to wet thoroughly all parts of the foliage without causing the drops to run in streams upon the leaves. The varieties of apples in the orchard will be referred to in giving the results of the experiments.

Three sets of experiments were made by spraying four, six, and eight times respectively, at intervals of about ten days, beginning May 6 to 10, and ending July 28. At the time of the first spraying at Carbondale, the apple-trees were in their first full bloom.

RESULTS OF EXPERIMENTS.

As a basis for the discussion of the principal results of this experiment, I have prepared the accompanying table showing especially the differences in quantity, number, and quality of apples borne by trees sprayed and by those without treatment. This table, it will be noticed, is divided into two parts, an upper and a lower, and for convenience in reference I have numbered the vertical columns from 1 to 12 and the horizontal sections of the table from 1 to 8.

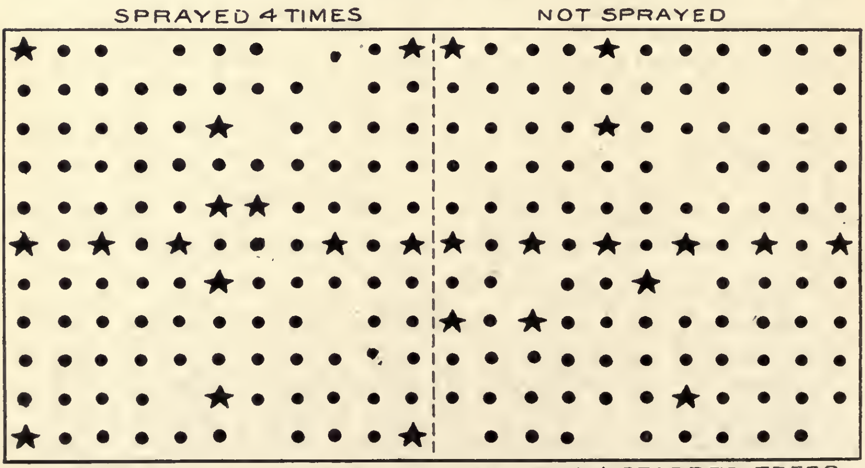
CURCULIO SPRAYING EXPERIMENTS.

Sections	Columns	1	2		3	4	5	6
	Plot	Times sprayed	Trees used		Apples picked			Injured per cent.
			No.	C't'd	Date	Bushels	Number	
1	I, Check Exper.	0 4	115 111	4 4	S. 16-20 S. 16-20	15.5 23.9	2,617 3,308	92.2 28.59
2	II, Check Exper.	0 6	34 32	3 3	Jl. 26-29 Jl. 26-29	11.4 16.	2,593 3,782	21.4 10 3
3	III, Check Exper.	0 6	20 20	3 3	S. 17 S. 17	16.25 22.	2,770 3,063	95.6 30.7
4	IV, Check Exper.	0 8	145 119	(9) 4 4	Jl. 15 S. 16-20	6.44 24.44	1,540 3,198	91.1 18 5

CURCULIO SPRAYING EXPERIMENTS.—Continued.

Sections	Columns	7	8	9	10	11	12
	Plot	Injuries prevented per cent.	Yield increased per cent.	Bushels			Value increased times
				No. 1	No. 2	No. 3	
5	I, Check Exper.	69.	54.	1.5 17.16	6.2 5.5	7.8 1.16	2.75
6	II, Check Exper.	48.	40.				
7	III, Check Exper.	68.	34.	.75 12.06	3.75 3.25	11.66 6.66	2.5
8	IV, Check Exper.	80.					

Orchard I (*Plot I.*).—By an examination of this table it may be seen (Section 1, Columns 1 to 5) that all the apples on 4 trees of Plot I. out of 111 of the Ben Davis variety which had been sprayed four times with arsenate of lead, were picked, measured, counted, and carefully examined between the 16th and the 20th of September, and that all the apples on 4 other trees of this plot out of 115 Ben Davises which had been left unsprayed as a check, were also picked, measured, counted, and similarly examined at the same time. These two lots of 4 trees each had been so selected at the beginning of the experiment from the whole number in each lot as to make the check lot the nearest possible duplicate of the lot which had been sprayed, except, of course, in the mere matter of spraying*.



ORCHARD NO I. APPLES COUNTED FROM STARRED TREES

*The four sprayed trees used for comparison with the four check trees are those starred in the sixth row from the middle line of the orchard. The four trees used as checks are among those starred in the fifth and sixth rows from the middle line.

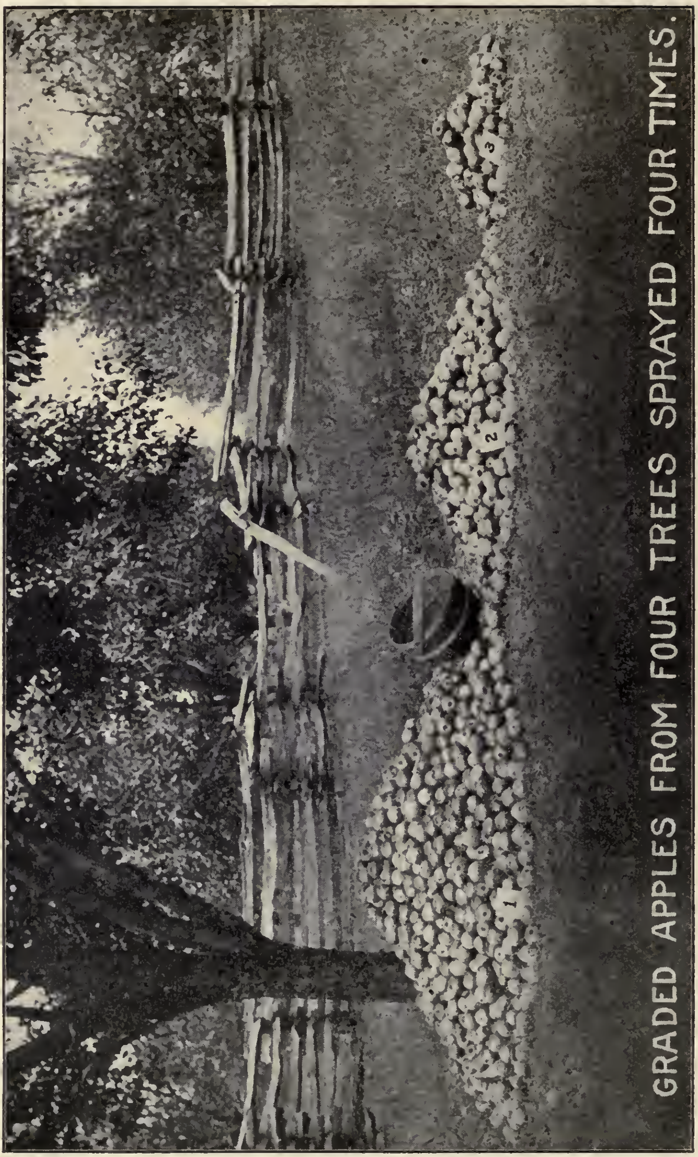
The 4 trees not sprayed yielded 15.5 *bushels* of apples, and the 4 trees sprayed yielded 23.9 bushels (Section 1, Column 4), the bulk of the yield being thus 54 per cent. greater for the sprayed trees than for those unsprayed (Section 5, Column 8). In other words the trees which had been treated, yielded one and a half times as large a *quantity* of apples as those which had not been sprayed.

The *number* of apples from the 4 trees not treated (Column 5) was 2,617, while that from the trees treated was 3,308—a difference of 26 per cent. in favor of the sprayed trees. That is, the sprayed trees bore a fourth *more apples* than those which had not been sprayed. We should notice, in passing, that the apples from the trees not treated ran 169 to the bushel, and that those from the treated trees ran 139 to the bushel—a difference of 21 per cent. in average size of fruit in favor of the sprayed trees. That is, the apples on the trees which had been sprayed were one fifth *larger,* on an average, than were those from the other trees.

All these differences were apparent without any special examination of the fruit with reference to injuries by curculios. When these curculio injuries were distinguished and tabulated (Column 6), it was found that 92.2 per cent. of the apples on the unsprayed trees had been injured by curculios making feeding-pits, egg punctures, or both, and that 28.6 per cent. of the apples on the sprayed trees were so injured. A simple calculation from these data shows (Section 5, Column 7) that 69 per cent. of the apples which would have been injured if no treatment had been applied, had been protected from injury by the arsenate spray.

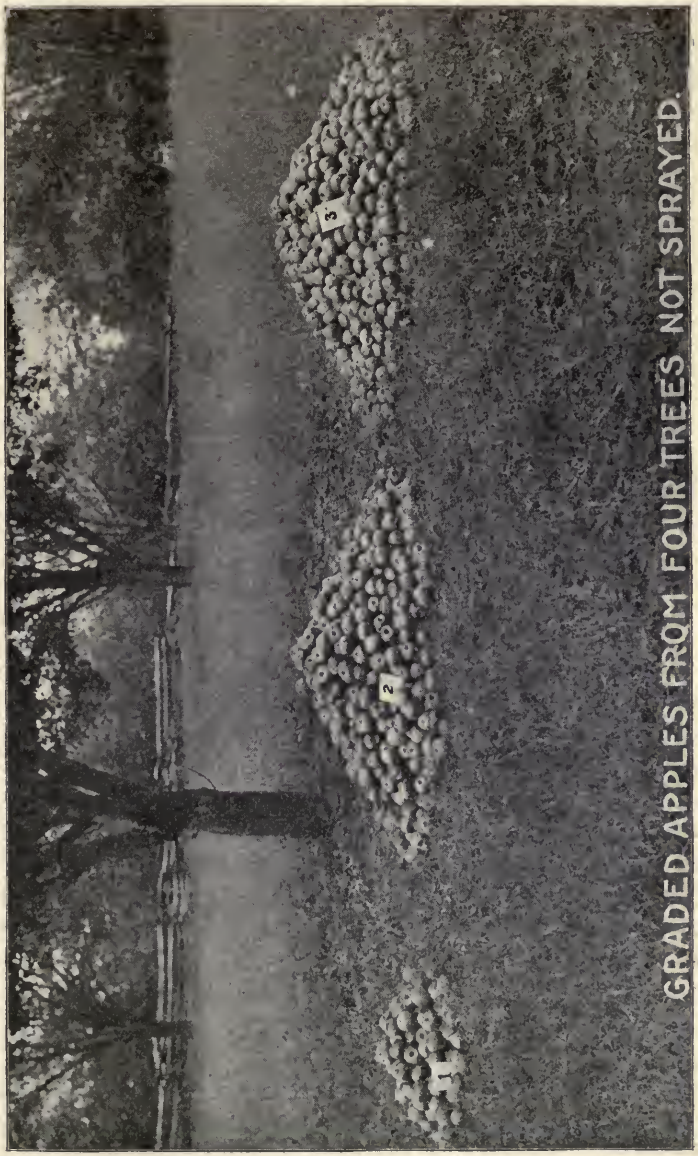
Next, the total product of both lots of trees was separately and very carefully graded as No. 1's, 2's, and 3's, by the standards of the American Apple Growers' Association adopted in 1903, (Section 5, Columns 9, 10, and 11,) with the result to show that the 4 check trees yielded 1½ bushels of No. 1's, and the 4 sprayed trees, 17.16 bushels; that the check trees yielded 6.2 bushels of No. 2's, and the sprayed trees, 5½ bushels; that 7.8 bushels of No. 3's were borne by the check trees, and 1.16 bushels by the trees which had been sprayed. (See Plates I. and II.)

According to the best estimate we can make of the market values of these three grades, if the No. 1 apples sell for $1, No. 2's might be expected to bring 75 cents, and No. 3's, 25 cents or thereabouts. Applying these estimates to these various lots of apples, it appears that the actual value of the crop from the treated trees was 2¾ times that from the trees which had not been treated (Column 12).



GRADED APPLES FROM FOUR TREES SPRAYED FOUR TIMES.

PLATE I.



GRADED APPLES FROM FOUR TREES NOT SPRAYED.

PLATE II.

To see whether the outer rows of trees were any more likely to be heavily infested by curculios than the inner,—whether curculios entering the orchard from outside would accumulate upon the outer rows,—three trees in the sprayed lot were examined, one from the middle and one from each end of the row farthest removed from the check. No differences in amount of curculio injury were found in these trees, as compared with the average for the plot in general, with the exception of one of the three, which stood at a corner of the orchard next a fringe of forest trees and brush. The fruit of this tree, notwithstanding the four thorough sprayings with arsenate of lead which it had received, had been injured by curculios to the amount of nearly 87 per cent., showing an extensive immigration into the orchard from the adjoining woodland. As this contained both hawthorn and wild cherry-trees it doubtless furnished a constant breeding ground for curculios.

Foreseeing difficulties of this kind, and also the probability of a mutual influence of check and experimental plots, the precaution had been taken to select, quite early in the season, for comparison, four trees from the center of each plot, and it is thus quite certain that no outside interference or intermingling of effects influenced the contrast obtained in this experiment.

Orchard 2 (*Plots II. and III.*).—We turn next to the second orchard (Sections 2, 3, 6, and 7), one half of which was sprayed six times in succession, the other half being left as a check. As a part of these apples were of an early variety (Benoni), and a part were of a late variety (Ben Davis), I will give the results for these two varieties separately.

Thirty-two Benoni trees (Plot II.) were sprayed six times in this experiment, in comparison with 34 Benoni trees left as a check, and the apples borne by 3 trees from each of these two lots were picked, measured, counted, and examined July 26 to 29 (Section 2, Columns 1 to 5), the two sets of trees having been so selected as to make the check lot the nearest possible duplicate of those which had been sprayed. The 3 trees not sprayed yielded 11.4 bushels of apples, and those which had been sprayed yielded 16 bushels (Column 4)—an increase of 40 per cent. in the bulk of the yield as a consequence of the spraying. The 3 trees which had not been treated bore 2,593 apples, while the 3 treated trees bore 3,782 (Column 5)—a difference of 47 per cent. in favor of the treated trees. That is, the sprayed trees bore nearly half as many apples again as those which had not been sprayed. The average size of the apples was approximately the same for both lots—228 per bushel for the untreated trees, and 236 for the treated.

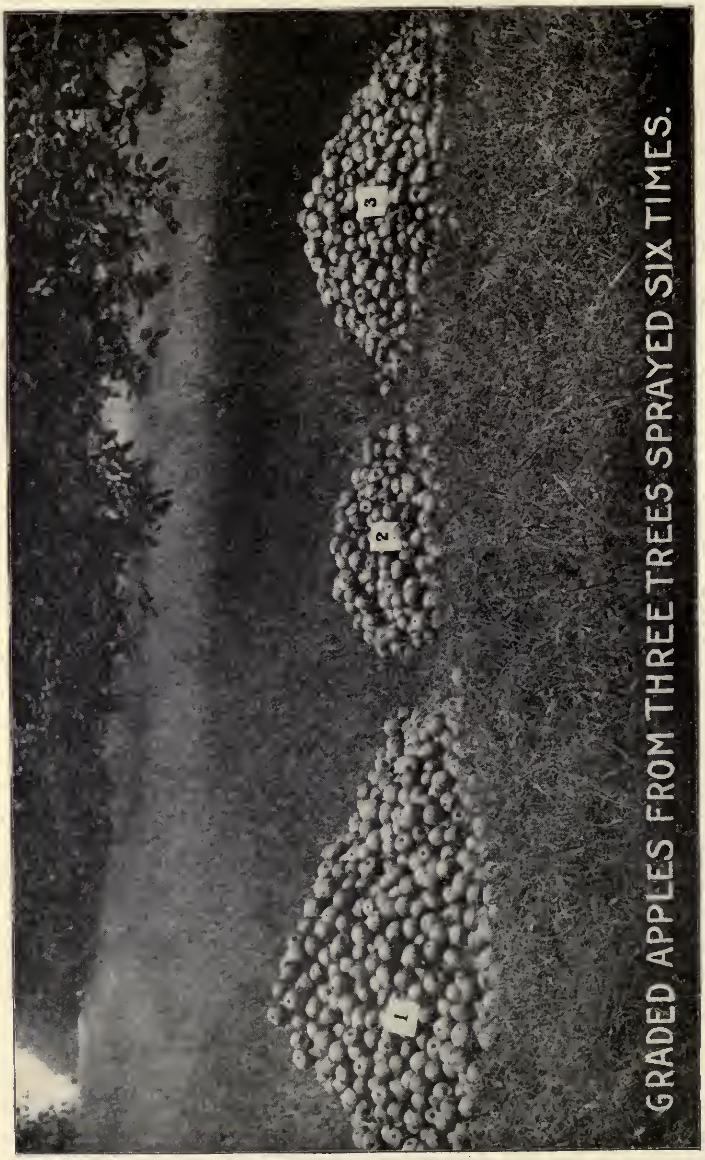
Turning next to the ratios of curculio injury to these Benoni apples (Column 6), we find that 21.4 per cent. of the fruit of the unsprayed trees had been injured by curculios, and 10.3 per cent. of that on the sprayed trees, 48 per cent. of the apples which would have been injured having been protected from injury by the arsenical spray. These Benoni apples were harvested in July, but were not graded into market classes. I consequently have no data as to the total money benefit of the spraying shown by this Plot II.

On the other part of this orchard (Plot III.), sprayed six times (Sections 3 and 7), were 20 Ben Davis trees which are to be compared with an equal number of this variety left unsprayed as a check. From each of these lots again 3 trees were taken for critical comparison of the product of those sprayed with that of those unsprayed (Section 3, Columns 1, 2, and 3). The final count on all these trees was made September 17. The 3 trees not sprayed gave 16¼ bushels of apples, while the 3 trees sprayed yielded 22 bushels (Column 4) —an increase of 34 per cent. in quantity of apples as a consequence of the spraying. The 3 Ben Davis trees which had not been treated bore 2,770 apples, while the 3 treated trees gave 3,063 (Column 5) —a difference of only 11 per cent. in favor of the treated trees. The unsprayed apples on these trees ran 170 to the bushel, and the sprayed apples, 139 to the bushel—a difference of 24 per cent. in size of fruit in favor of the trees which had been sprayed.

With respect to the curculio injury to these Ben Davis apples we find that 95.6 per cent. of the unsprayed fruit had been injured by curculios, and 30.7 per cent. of that sprayed; or, in other words, that 68 per cent. of the apples which would have been injured had been protected from injury by the treatment received.

Looking now to the quality of the fruit from these Ben Davis trees, which had been sprayed six times in all (Section 7, Columns 9, 10, and 11), we find that the 3 unsprayed trees examined gave a yield of ¾ of a bushel of No. 1 apples, while the 3 sprayed trees yielded 12.06 bushels; that the unsprayed trees gave 3¾ bushels of No. 2's, the sprayed trees 3¼ bushels; that the unsprayed trees yielded 11⅔ bushels of No. 3's, and the sprayed trees 6⅔ bushels. (See Plates III. and IV.) Reducing these quantities to comparable money values by the prices already assigned, we find that the actual value of the crop from the treated trees was 2½ times that from the trees which had not been treated.

Orchard 3 (*Plot IV.*).—In the third and last orchard on which I have to report, the check and the experimental sections do not correspond closely, the sprayed trees being all Winesap and Ben Davis, late varieties only, and the check lot almost entirely of early vari-



GRADED APPLES FROM THREE TREES SPRAYED SIX TIMES.

PLATE III.

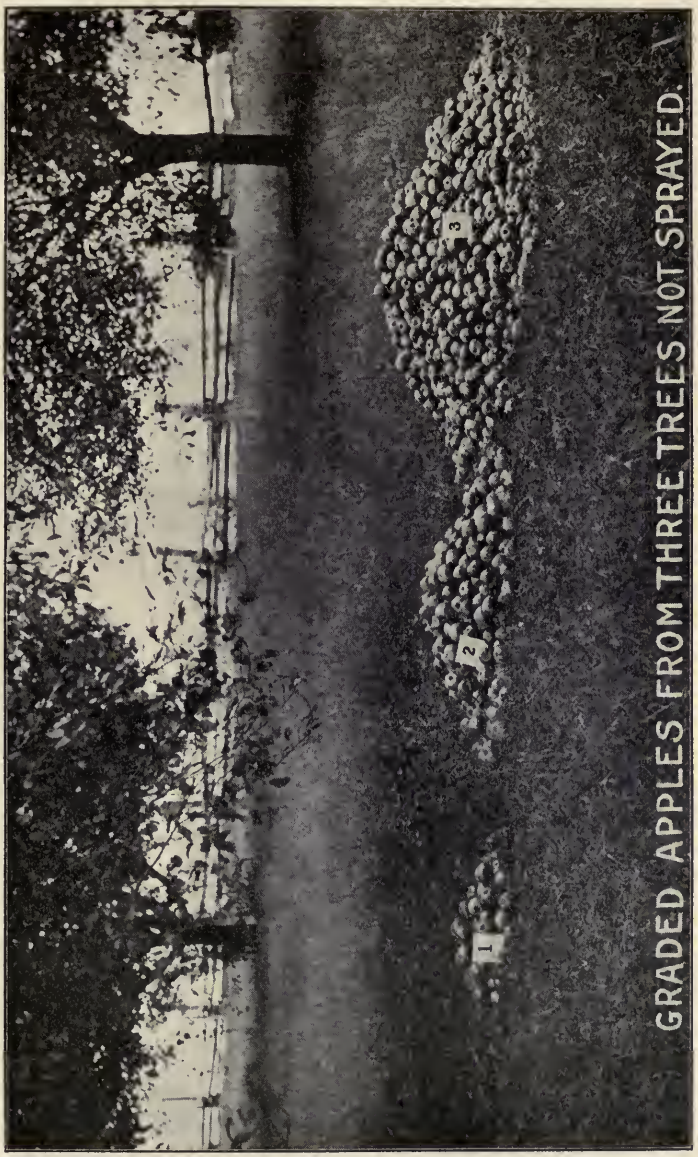


PLATE IV.

eties. As the early varieties were harvested July 15, they were less exposed to injury than the fruit on the sprayed trees, which was harvested from September 16 to 20. This is a difference, however, which tends to diminish the contrast between the sprayed and unsprayed trees, and thus to show, if anything, a smaller result from spraying than was actually obtained.

The Winesap and Ben Davis trees, 119 in number, were sprayed eight times in succession, and the fruit from 4 of these trees (3 Ben Davis and 1 Winesap) was picked and examined with reference to curculio injuries. The unsprayed orchard used as a check on this experiment contained 145 trees, all Sops of Wine and other early varieties except 4 Ben Davis (see Section 4, Columns 1, 2, and 3). The fruit from 9 of these check trees was examined July 15, all Sops of Wine except 1 Ben Davis. These yielded 3,463 apples, making 14¾ bushels, equal to 1,540 apples, or 6.44 bushels from 4 trees (Columns 4 and 5), while the 4 trees sprayed, the apples from which were picked September 16 to 20, yielded 3,198 apples, making 24½ bushels. These differences in number of apples and bulk of yield can not properly be taken into account in this case, because both might well be attributable, at least in part, to the difference in variety between the sprayed and the check trees from which the fruit was counted.

The curculio injuries on the 9 unsprayed trees had affected an average of 91 per cent. of the apples (Column 6), and on the 4 sprayed trees, an average of 18½ per cent., from which it appears (Section 8, Column 7) that 80 per cent. of the apples which might have been injured by curculios if no treatment had been applied, had been saved from such injury by the arsenical spray. Here again it is possible that a varietal difference in susceptibility to curculio injury may have affected these percentages.

COST OF THE OPERATION.

The reader will be especially interested to know the cost of our operation, figured in terms practical to the fruit grower. I have worked this out in full detail for the 292 trees sprayed in these orchards, including the actual price of materials purchased in the ordinary markets, the amount of materials used, and the labor of application at $1.25 a day and board for men employed, and $2.50 a day and feed for a team. Without entering into details, unnecessary for my purpose, I find that the total cost ranges from 4 to 5 cents per tree for each treatment, or 17 cents per tree for the four treatments found most effective. Of this only 2 cents was for materials, the remaining 15 cents being for labor of man and beast, much of which, in many cases, the fruit grower might supply without special outlay.

SUMMARY OF SPRAYING RESULTS.

Finally, to sum up in a word the most important practical results of the orchard experiment with arsenate of lead, we may say that four sprayings of apple-trees of late varieties, exposed to a very heavy attack by the plum-curculio, the first spraying applied in early May just as the trees are coming into bloom, and the others at intervals of 10 days thereafter, the whole operation costing 17 cents per tree, may be expected to increase the yield of the orchard about one half, to increase the average size of the fruit by about a fifth, and so to improve the quality of the apples that they should be worth from 2½ to 3 times as much as if the orchard had not been sprayed.

POISON TESTS OF SPRAYED APPLES.

The arsenate of lead used in experiments described in this paper is an unusually adhesive insecticide, remaining upon trees in visible quantity weeks and even months after it has been applied. Evident traces of the mixture were still visible in October on leaves which had fallen from trees sprayed with the arsenate of lead July 4. In view of this fact it seemed to me important that experiments should be made to determine the amount of poison carried by apples treated with this insecticide within a reasonable limit of time after the spray was applied. I consequently directed, in 1905, the spraying of apple-trees with various arsenical compounds, and among others with the home-made arsenate of lead, and obtained analyses of the peelings of apples so sprayed taken from 2 trees within a day of the application of the insecticide, and from a third tree 2 months thereafter.

The first of these trees, of the Duchess variety, received 2 sprayings with the arsenate of lead—the first June 9 and the second July 4—not having been previously sprayed at all that year. In both these sprayings the insecticide was used at 4 times the common strength—12½ ounces of acetate of lead and 5 ounces of arsenate of soda to 12½ gallons of water instead of the usual 50 gallons.

The next day, July 5, six apples, averaging two and a fourth inches in diameter, were carefully picked from this tree by the stem and peeled at once, the apple being held upon the point of one knife while it was peeled with another, to avoid removing any part of the poison unnecessarily. The peelings were then dropped into a dry, clean, new Mason jar and submitted for chemical analysis to Dr. Wm. M. Dehn, of the Chemical Department of the University of Illinois. It should be said that the weather in the interval between spraying and collection of the apples had been dry. According to Dr. Dehn's

report, these apple peelings thus collected yielded 36.6 parts per million of arsenious acid, enough to equal .2562 grains of arsenic to an avoirdupois pound of the sample peelings. This would mean that one would have to eat approximately four pounds of apple peelings to get a grain of arsenic if the fruit were taken the day after spraying from a tree which had received four times the usual strength of this insecticide.

Another tree, a Benoni, differed especially in two respects from the foregoing. It had been sprayed three times by the owner earlier in the season, and it was sprayed twice by us—June 9 and July 4—but with arsenate of lead in the strength usual in practical orchard work, that is, 12½ ounces of acetate of lead and 5 ounces of arsenate of soda to 50 gallons of water. The earlier sprayings were as follows: First spraying about April 3, before the appearance of the bloom, with 3 pounds copper sulphate, 5 to 6 pounds lime, 2 ounces arsenate of soda, and 2 ounces Paris green, to 50 gallons of water; second spraying about April 26, just after the bloom had fallen, with 2 pounds copper sulphate, 1 pound Lorenberg's arsenate of lead, 2 ounces Paris green, 3 to 4 pounds lime, and 50 gallons of water. Rain fell more or less for three days after this second spraying. The third spraying, about May 3, was with 2 pounds copper sulphate, 3 to 4 pounds lime, 1 pound Lorenberg's arsenate of lead, 2 ounces Paris green, and 50 gallons of water.

From this tree six apples averaging two inches in diameter were picked July 5, the day after our own second spraying, with the precautions described above. The peelings tested by Dr. Dehn yielded 32.9 parts of arsenious acid per million, equivalent to .2303 grains of arsenic per pound of the samples.

It will be noticed that, although the insecticide here used contained only one fourth as much of the arsenate as that applied to the Duchess tree, the percentage of arsenic remaining on the fruit was nearly as large.

The third tree treated was a Rome Beauty, sprayed, like the preceding, three times, April 3, April 26, and May 3, approximately, with combinations of Bordeaux mixture and arsenical insecticides, and further sprayed, June 9 and July 4, with home-made arsenate of lead at the rate of 12½—5—12½; that is, like the first tree, with four times the usual strength.

The apples were picked from this tree September 4, two full months from the time of spraying. Those chosen showed more than the average amount of residue of the insecticide on the fruit. They were picked into baskets, poured into a box where they were packed closely by hand, and shipped to the office at Urbana, being given average

shipping treatment. Ten apples were later taken from the box and carefully peeled, the peelings being submitted, as before, to Dr. Dehn for examination. Notwithstanding the long exposure in the orchard, the report on the arsenical contents of this material is very similar to that of the preceding determinations. The arsenious acid was found at the rate of 40.1 parts per million, enough to give .2807 grains per pound of the apple peelings. One would thus have to eat about three and a half pounds of these peelings to get a grain of arsenic.

Two grains of arsenic is a fatal dose, and one thirtieth to one tenth of a grain is a medicinal dose. For the first, one would have to eat seven or eight pounds of these apple peelings; and for the second, from two to seven ounces. While these facts are not at all alarming, they suggest discretion in the use of this insecticide and in the subsequent handling and disposal of the apples. We also need further experiment with various strengths of the spray and with various kinds and amounts of subsequent exposure of the fruit. Nevertheless, in view of the fact that apple peelings are rarely eaten in any quantity, I think that no hesitation need be felt to substitute the arsenate of lead for the more usual insecticide sprays if the facts here given are borne in mind and duly allowed for.

The Neutral Zone in Spraying Experiments.

It has been customary in making field insecticide experiments to apply the chosen treatment to a certain area, leaving a corresponding area immediately beside it untreated, as a check, the utility of the treatment being determined by a comparison of subsequent conditions on these two tracts. Attention has already been called by Gillette,* Weed,† and myself,‡ to the fact that the results of such experiments must be somewhat affected by the spread of insects from the so-called check plot to the experimental plot, but nothing has been done to demonstrate this proposition experimentally, or to show just how important this mutual influence of check and experimental plots may be.

In the spraying experiment conducted in Orchard I., as above described in this article, the opportunity was improved to ascertain to what extent the curculios spread from one part of the orchard to another—to what extent, that is, one must guard against vitiation of results of spraying experiments by the spread of the curculios from unsprayed trees to those which have been sprayed. This or-

*Bull. 9 (1890), Ia. Agr. Exper. Station, pp. 383-384.
†Bull. 23 (1890), Ohio Agr. Exper. Station, p. 226; Agricul. Science, Apr., 1890, p. 97.
‡"Arsenical Poisons for the Codling-moth." Bull. 1 (1887), Office State Ent. Ill., p. 9; Fifteenth Report, State Ent. Ill., p. 13.

chard, it will be remembered, was divided into two equal parts, each virtually square, on one of which all trees were sprayed four times with arsenate of lead, beginning May 6 and following at intervals of ten days thereafter, while the other part was left unsprayed as a check. The apples in this orchard were of the Ben Davis variety, and were harvested September 20. At this time all the apples borne by three trees which had not been sprayed, but which stood in the row next the sprayed half of the plot, were counted and examined in comparison with the product of ten other trees taken at various points in this unsprayed part of the orchard. (See diagram, p. 270, and table on p. 284). Eighty-one and five tenths per cent. of the apples on these 3 trees next the experimental plot had been injured by the curculios, and 90⅓ per cent. of the apples on the 10 trees farther back,—a difference of 8.8 per cent. of all the apples on these trees, which can only be accounted for on the supposition that more curculios went from the three trees nearest the sprayed half of the orchard *into* that half than came into it *from* that half.

Next, three trees which had been sprayed and which stood in the row nearest the unsprayed part of the orchard were similarly examined, with the result that 43⅓ per cent. of the apples on these trees were found to have been injured by curculios, while 26½ per cent. of the apples on 10 other trees taken elsewhere in this sprayed plot were so injured. That is, 16.8 per cent. more of the fruit on the trees standing nearest the unsprayed portion was injured than on the trees farther back.

It will be seen that the increase of average injury to apples on unsprayed trees near the check plot was nearly twice as great as the decrease of injury on the unsprayed trees standing next the experimental plot. This can only mean that the excess of curculios on the unsprayed fruit to which their greater injury was due did not all come from the unsprayed trees in the adjoining row, but that approximately half of them must have come in from remoter parts of the experimental plot. In order to see how far this mutual effect of one plot on the other actually extended inward in either direction from the dividing line, apples were picked and counted separately for each tree from a series of 14 trees running lengthwise of the orchard at right angles to the dividing line between the two plots. It was found in this way that notable dimunition of curculio injury on the one side and increase on the other did not extend so far as the third row from the dividing line in either direction; in other words, that it seemed limited to the first two rows on either side of that line.

To test this conclusion in a more general way, the percentages of curculio injury to apples were figured separately for all trees in each cross-row from which any fruit was picked, beginning at the outer end of the sprayed half of the orchard and ending at the opposite end of the unsprayed half. The details are shown on the ac-

companying table (p. 284), from which it will be seen that 12 trees in six different transverse rows of the sprayed half of the orchard, ranging from the first to the ninth row, bore from 26 to 30 per cent. of injured apples,—excluding for the moment a single exceptional tree in the seventh row, which gave but 16 per cent. of injury. That is, with this exception, the ratios ran from row to row with virtual uniformity as far as the third row from the dividing line. In the other half of the orchard, that left unsprayed as a check, the injury on 10 trees distributed through six rows—from the fourteenth to the twenty-second—ranged from 87 to 99 per cent., and in this series also there is no uniform progression as one goes from the dividing line outward.

We may make this influence of a proximity of check and experimental plots more definitely apparent by saying that if the two adjacent rows only had been brought into comparison the difference in injured apples would have been only 38 per cent., while the real effect of the treatment was a difference of 63 per cent. Or, to put the facts still more definitely, a comparison of the product of the adjacent rows would indicate a saving, by spraying, of 47 per cent. of the apples which would otherwise have been injured, while the real saving was one of 70 per cent. The apparent benefit would be but two thirds the actual.

We find, in short, two to four rows running through the center of this orchard, one or two in each of the two plots, the product of which has been rendered unfit for use in an exact comparison of the condition of these two plots with reference to experimental results. Such a strip must evidently always exist under similar circumstances; a kind of neutral zone belonging properly to neither plot, and unfit for comparison or for use in a discussion of the outcome of an experiment. The importance of this conclusion is evident when one scans the published statements of similar experiments and finds that in many cases the adjoining plots are so narrow that nearly or quite all of both must lie in this neutral zone. Sometimes, indeed, one can not learn from the description of an experiment the form or dimensions of the plots, and consequently can not judge how far some portions of each or either may have been removed from this central belt. Any experiment of the kind on diffusible insects or fungi which does not take these facts into account, and from the discussion of which a sufficient central strip is not omitted, must be regarded as unsatisfactory, if not rejected outright as inexact.

Both the amount and the extent of the mutual influence of check and experimental plots will vary greatly with different insects, and with the same insect species under different conditions of abundance and different kinds of treatment. Where infestation is unusually heavy this interference with effects of treatment would, other things being equal, be more pronounced. To determine, in any case, how

much of a central strip must be omitted, it would be necessary to make some such preliminary test as I have described, or, if the entire product of the plots were harvested, to keep the different parts of it distinct, rejecting those data which show an evident influence of one plot upon the other.

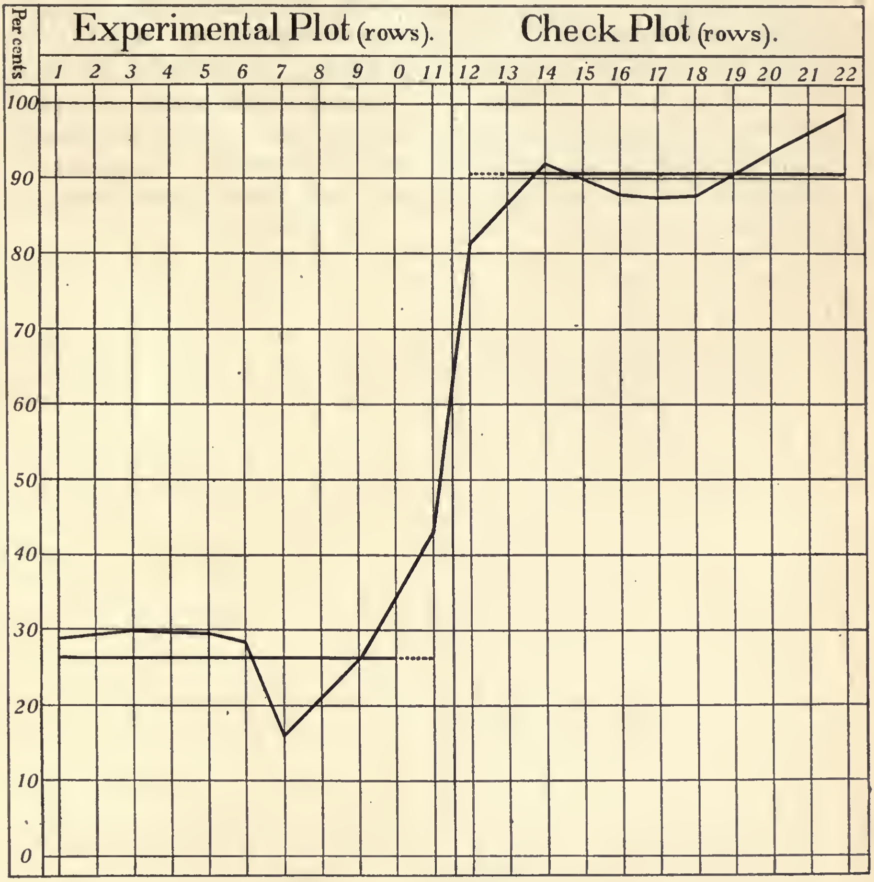
In an ordinary plot experiment, if I infer from the outcome of the treatment of a lot of trees in the midst of an orchard what will happen if an entire isolated orchard were similarly treated, I tacitly assert that such a plot, so situated, is so like an isolated orchard in all that concerns my experiment that the one may be substituted for the other. As a matter of fact, however, while a small part of an orchard is analogous to the whole of it in many particulars, it may differ from the whole in just those particulars and conditions which most strongly affect my problem.

Since reasoning by analogy is the only process possible in such a case, we must first make this analogy practically complete—must establish the essential similarities between our experimental plot and an entire orchard—before we can reach any safe conclusion as to the practical application of the experimental results. This I have done to the best of my ability in the experiment here referred to, and I venture to think that like results may be expected, under similar conditions, from a repetition upon entire orchards of the treatment here described.

ORCHARD I. SPRAYED PLOT, ROWS 1 TO 11; AND CHECK, ROWS 12 TO 22.

Row	Trees examined	Per cent. injured	Average
1	2	28.95	
2	0		
3	1	29.89	
4	0		
5	3	29.73	26.53
6	4	28.59	
7	1	16.	
8	0		
9	1	26.	
10	0		
11	3	43.33	43.33
12	3	81.5	81.5
13	0		
14	2	92.23	
15	0		
16	3	88.08	
17	1	87.7	90.33
18	2	87.19	
19	0		
20	1	93.79	
21	0		
22	1	98.96	

DIAGRAM OF SPRAYING EFFECTS WITH ARSENATE OF LEAD.
(Showing mutual influence of check and experimental plots.)



The above diagram is simply a graphic representation of the data of the preceding table. The vertical lines represent the rows of trees in Orchard 1, except the central line, which marks the division between the half of the orchard which was sprayed and the half left unsprayed as a check. The horizontal lines, numbered from 10 to 100, indicate percentages of injured apples. The broken line crossing the diagram from left to right intersects the vertical line for each row at a point corresponding to the percentage of injured apples from that row. It will be noticed that the eleventh row of the series is the experimental row next to the check plot, and that the twelfth is the check row next to the experimental plot. The influence of these plots one upon the other is shown by the strong upward course

of the broken line from the ninth to the eleventh rows, and the downward course from the fourteenth to the twelfth. The short horizontal lines, one on each side of the diagram, indicate the *average* percentage of injury on check and experimental plots respectively, with the exception of rows eleven and twelve. The distance between the inner ends of these lines is a measure of the benefit resulting from the spray, and the distance from the inner end of each line to the point where the broken line crosses the vertical, is a measure of the influence of the other plot through the unequal interchange of curculios.