POTATO SPRAYING EXPERIMENTS IN 1902.

F. C. STEWART, H. J. EUSTACE AND F. A. SIRRINE.
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The Bulletins published by the Station will be sent free to any farmer
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SUMMARY.

The Station has undertaken to determine how much the yield of potatoes may be increased, on the average, by spraying the plants with bordeaux mixture for ten consecutive seasons; also, which is more profitable, to spray every two weeks throughout the growing season, or to make but three applications. The experiments are to be carried on in two localities; viz., on the Station farm at Geneva and on Long Island. At each place the area of the experiment field is to be three-tenths of an acre each season. Each year, or as often as advisable, there will be published a bulletin giving the results up to date; also other information on the spraying of potatoes.

The present bulletin gives the results of the first year’s work. At Geneva, the rows sprayed three times yielded at the rate of 317 1/3 bushels per acre; those sprayed seven times 342 1/3 and those not sprayed, 219. Thus, three sprayings increased the yield 98 1/3 bushels per acre and seven sprayings, 123 1/3 bushels. The increased yield on sprayed rows was due, chiefly, to the prevention of late blight.
On Long Island the rows sprayed three times yielded at the rate of 295½ bushels per acre; those sprayed seven times, 312½ and those not sprayed, 267½. The increased yield due to three sprayings was 27½ bushels per acre, while that due to seven sprayings amounted to 45 bushels per acre. There being no damage from blight or "bugs," the increased yield on the sprayed rows in the Long Island experiment must have been largely due to better protection against flea-beetles.
INTRODUCTION.

For more than fifteen years it has been known that potato blight may be prevented by spraying the plants with bordeaux mixture. Potato spraying experiments have been made by the United States Department of Agriculture, by many of the experiment stations and in Europe. With but few exceptions these experiments have shown that the yield of potatoes may be considerably increased by spraying, and it is the consensus of opinion among experts, that, under most conditions, the spraying of potatoes is a profitable operation. The results of these experiments and the conclusions deduced from them have been widely published in various publications of the United States Department of Agriculture, in experiment station bulletins, in the agricultural papers and through the medium of farmers' institutes.

Nevertheless, there is probably no place in the United States where the spraying of potatoes is generally practised by farmers—certainly none in New York State. In New York very few farmers spray their potatoes regularly. In seasons when the blight is epidemic, as it has been during the past season, many attempt to protect their potatoes by spraying, but in most cases only partial success is attained because the spraying is commenced too late and not done thoroughly. Evidently, farmers in this State are not yet convinced that it pays to spray potatoes regularly. As nearly as we are able to determine, the causes of this unbelief in the profitableness of potato spraying are as follows:

(1) Blight is not destructive every season. While occasionally it nearly ruins the crop, there are other seasons when it does but little damage, and still others when there seems to be no damage whatever. Consequently, farmers look upon spraying as a matter of insurance. While they readily admit that there is profit in spraying in seasons when potatoes blight badly, they do not believe that it pays on the average.

(2) In many cases the spraying is not done thoroughly, and consequently the results are unsatisfactory.
(3) Few farmers who spray potatoes know accurately how much they have increased the yield by spraying. Usually no portion of the field is left unsprayed; hence there is no basis for comparison except the unsprayed fields of neighbors. Even where a few rows are left unsprayed for comparison the difference in yield is usually guessed at and rarely determined accurately by weight or measurement.

(4) Often there is a lack of confidence in the results obtained at experiment stations. Many persons believe that in experiments made at the stations the potatoes have been given an extra chance and that it is impossible to duplicate the results in ordinary farm practice.

DETAILS OF THE EXPERIMENTS.

OBJECT.

The chief object of the experiments herein reported was to ascertain how much the yield may be increased, on the average, by spraying potatoes in New York State. With this point definitely determined, it will be considerably easier to give a correct answer to the question, Does it pay to spray potatoes regularly? Since the profit to be derived from spraying depends upon the relation existing between the expense of the treatment and the value of the increase in yield due to the treatment, the ideal experiment would be one which takes both of these factors into account; but in order that the test might be a fair one, so far as the expense is concerned, it would be necessary to have several acres included in the experiment. This would have made more work than it was deemed advisable to undertake, and so it was decided to attempt only the solution of the simpler but more important part of the problem; namely, the average increase in yield. We consider the question of increase in yield more important for the reason that it varies greatly from year to year, whereas the expense of spraying varies but little in different seasons.

It is possible that next season the Station will undertake some supplementary experiments especially designed to determine the expense of spraying.
A second object of the experiments was to determine which is the more profitable: To spray every two weeks throughout the season, as is usually recommended; or to make only three sprayings during the season.

**Duration.**

Of course it is necessary to continue the experiments several years before a reliable average can be obtained. The chief cause of variation in the results is the variation in weather conditions, and since the average weather conditions for any period of ten years approximate very closely the average for any other period of ten years, it would seem that the proper length of time to continue the experiments is ten years. Accordingly, the Station expects to spray potatoes every year for ten consecutive years, and the plan of the experiments each year will be the same as in this first year's work. Each year the increase in yield per acre due to spraying will be accurately determined, and at the end of the ten years the results will be averaged.

However, it is not the intention to withhold the publication of the results until the experiment is finished. Each year, or as often as seems advisable, there will be published a bulletin giving a detailed account of the results of unpublished experiments and a summary of the results of the preceding years, in order that the public may be kept informed as to the progress of the experiments. These bulletins will also contain other matter pertaining to potato spraying and potato blight. Therefore, this bulletin is the first of a series on the subject of potato spraying.

**Location of Experiment Fields.**

In some localities potatoes blight more frequently and more severely than in others, and, consequently, spraying produces a larger increase in yield in some localities than in others. On this account it was thought best to conduct the experiments in at least two localities. One of the places selected was on the Experiment Station farm at Geneva and the other on the farm of Mr. F. A. Sirrine, three miles north of Riverhead, on Long Island. Throughout the entire period of ten years during which the experiments run the experiment fields will be confined to these same two farms, but, of course, not on the same plats.
ARRANGEMENT AND AREA OF PLATS.

In order to eliminate as far as possible the influence of inequalities in the soil, etc., the plats were arranged in the manner shown in the accompanying diagram:

**Diagram Showing Arrangement of Plats in the Experiment at Geneva.**

<table>
<thead>
<tr>
<th>Section</th>
<th>O. A</th>
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<td>14.</td>
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</table>

Sprayed 3 times.

Sprayed 7 times unsprayed.

Sprayed 3 times.

Sprayed 7 times.

Unsprayed.

Sprayed 3 times.

Sprayed 7 times.

Unsprayed.

Sprayed 3 times.

Sprayed 7 times.

Unsprayed.

Sprayed 3 times.

Sprayed 7 times.

Unsprayed.

Unsprayed.

Rows O. A and O. B were really not in the experiment. They were planted in order to avoid having any outside rows in the experiment. Otherwise the rows 1 and 15 would not have had an equal chance with the other rows.

Series I consisted of rows 1, 4, 7, 10 and 13, which were sprayed three times.

Series II consisted of rows 2, 5, 8, 11 and 14, which were sprayed seven times.

Series III consisted of rows 3, 6, 9, 12 and 15, which were not sprayed.

The area of the experiment field at Geneva was exactly three-tenths of an acre, and of the one at Riverhead the same.

At Geneva the rows were 290.4 feet long and 3 feet apart. Hence each row contained exactly one-fiftieth of an acre and each series one-tenth of an acre.
At Riverhead the rows of the different series alternated with each other, as at Geneva; but in this case there were 12 rows 363 feet long and 3 feet apart. Each row contained one-fortieth acre and each series, consisting of four separate rows, one-tenth acre.

FITTING, PLANTING, CULTIVATION, ETC.¹

At Geneva.—In the season of 1901 part of the field grew corn and part cow peas. In the spring of 1902 the land was plowed and sown with oats before it was decided to use it for the potato experiment. On May 16 furrows were opened with a plow and commercial fertilizer² applied in the furrows at the rate of 1,000 lbs. per acre. The fertilizer was worked in with a hoe.

The seed was of the variety Rural New Yorker No. 2, which is one of the most popular varieties in central New York. The seed pieces used were whole tubers of the size of a hen’s egg. A short time before planting they were given the formalin treatment³ for scab. They were planted on May 16 and 17, 15 inches apart in the row, the rows 3 feet apart, and covered with a hoe. The cultivation was all done with a horse cultivator, which was used five times. In the last cultivation the dirt was thrown toward the plants so as to hill them slightly. There was no hand cultivation except the pulling of a few large weeds late in the season.

The soil was a black, clay loam with a clay subsoil. The field sloped gently toward the east, giving good drainage.

At Riverhead.—The previous crop for two years had been timothy and weeds. The land was plowed six to eight inches deep on April 13 and then harrowed three times. After treat-

¹ These cultural details, although somewhat irrelevant, are given here for the reason that many persons desire to know how yields of 325 and 350 bushels per acre were obtained in the experiment at Geneva while potato yields in the surrounding country ranged from 25 to 100 bushels per acre.

² The fertilizer used was from a lot which was in one of the Station barns when they were destroyed by fire on May 7. Before the fire the fertilizer analyzed as follows: Potash, 4.59 per ct.; nitrogen, .83; available phosphoric acid, 14.11. Its market value was about $26 per ton.

³ Tubers soaked two hours in a solution containing one pint of formalin in 30 gallons of water.
ment with corrosive sublimate for scab, planting was done by hand on April 23 with whole tubers of the size of a hen's egg, placed 15 inches apart in the row and the rows 3 feet apart. The variety of potato was Carman No. 1, which is very popular on eastern Long Island. Home-mixed fertilizer, having the formula 4-10-4 and costing $27.20 per ton, was used at the rate of 1,100 pounds per acre. The trenches for planting were made by going twice over each row with a fertilizer drill, and the tubers were covered with the discs of an Aspinwall potato planter. A cultivator was used once and a weeder once before the plants came up. After the plants were up the weeder was used twice and the cultivator six times. At the last cultivation the plants were slightly hilled. A few weeds were pulled and a few cut out with a hoe. The soil was well-drained sandy loam containing some gravel, and the field sloped moderately toward the southeast.

**PREPARATION AND APPLICATION OF THE BORDEAUX MIXTURE.**

The methods of preparing and applying the bordeaux mixture were practically the same at Geneva and at Riverhead. The bordeaux was made according to the 1-to-8 formula; that is, one pound of copper sulphate was used in each eight gallons of bordeaux, or six pounds to the barrel. This is the formula usually recommended for spraying potatoes. The amount of lime required was determined by the yellow-prussiate-of-potash test.

The bordeaux was applied by means of a knapsack sprayer, except in the first spraying (June 25) at Geneva, in which case it was applied with a barrel pump, such as is used for spraying trees.

The spraying was done with great thoroughness, particularly at Geneva. No attempt was made to spray the under surface of the leaves, but practically every leaf was well coated above. When the plants became full grown the foliage of adjacent rows intermingled, and thus it was impossible to thoroughly spray the rows of series I and II without getting some of the mixture on the adjacent unsprayed rows of series III. However, this was avoided as much as possible.
DATES OF SPRAYING.

At Geneva: Series I.—This series, consisting of rows 1, 4, 7, 10 and 13, was sprayed three times with bordeaux mixture—July 10, 23 and August 12. The applications were made at such times as they were most needed. It was impossible to delay the first application longer than July 10, because at that time large numbers of "bugs" had commenced to feed, and unless these had been killed at once they would have done great damage. To kill the "bugs" paris green was added to the bordeaux mixture at the rate of 10 ounces to 50 gallons. The treatment was entirely successful. Five days later there was scarcely a living "bug" to be seen.

It was thought advisable to make the second spraying on July 23, because during the preceding week there had been frequent showers and the weather seemed favorable to blight. In fact, the occurrence of late blight (Phytophthora) had already been reported from Delhi (July 15) and Ilion (July 21). In this second spraying bordeaux alone was used.

Late blight made its first appearance in the experiment field on July 28. At this time the disease was already epidemic among early potatoes at Geneva, Seneca Falls and other places in central New York; but it was not yet common among late potatoes, and in the experiment field it made slow progress even on the unsprayed rows.

The third and last spraying was made August 12 with bordeaux alone.

Series II.—This series consisted of rows 2, 5, 8, 11 and 14. It was the intention to spray it according to the directions usually given for spraying potatoes; namely, "Commence spraying when the plants are six to eight inches high and repeat the treatment at intervals of 10 to 14 days as long as the plants remain green."

In all, seven sprayings were made, as follows: June 25, July 10, 23 and 30, August 12 and 26 and September 10. Paris green was used in only one spraying, that of July 10, in which case it

4 The word "bugs" as used throughout this bulletin refers to the striped Colorado potato beetles, Doryphora decemlineata. Properly speaking, these insects are beetles and not bugs, but to farmers they are known as "bugs." Moreover, "bugs" is a shorter name and for that reason it will be used in this bulletin.
was used at the rate of 10 ounces to 50 gallons, as on series I, and with equally good results. On account of the weather conditions being exceptionally favorable to late blight during the week following July 23 it was considered advisable to spray on July 30, although only a week had elapsed since the last spraying. However, subsequent events showed that this was unnecessary. It might just as well have been postponed until August 6, which would have made the interval between sprayings two weeks, as originally planned. Had this been done, the next two sprayings would each have occurred one week later, and the seventh spraying might then have been omitted.

Series III.—Series III consisted of rows 3, 6, 9, 12 and 15. They were not sprayed at all with bordeaux, but were treated twice (July 10 and July 30) with paris green in lime water to kill the "bugs." The paris green was used at the same rate as on series I and II; that is, at the rate of 10 ounces to 50 gallons of water. Although the "bugs" were practically all killed by the application made July 10, the same as on series I and II, sprayed with bordeaux, it was necessary to make a second application to series III on July 30; whereas, series I and II required but the single treatment for "bugs." However, the "bugs" were so completely controlled by the two treatments that they did not harm the plants.

At Riverhead: Series I.—This series consisted of four rows—Nos. 2, 5, 8 and 11, which were sprayed with bordeaux mixture three times; namely, on May 26, June 20 and July 22. No poison was used except in the second spraying, when "green arsenoid" was added to the bordeaux at the rate of five ounces to 50 gallons.

Series II.—This series consisted of four rows—Nos. 1, 4, 7 and 10. They were sprayed with bordeaux mixture seven times; namely, on May 26, June 3, 20 and 30, July 11 and 23 and August 5. "Green arsenoid" was added to the bordeaux on June 20 (five ounces to 50 gallons), on June 30 (six ounces to 50 gallons), on July 8 (eight ounces to 50 gallons), and on July 23 (five ounces to 50 gallons). There was no necessity for using poison on this series to kill "bugs," because there were none worth mentioning; but flea beetles were plentiful and poison was used
frequently in an attempt to kill them. Their ravages were certainly lessened and some dead flea beetles were actually found.

Series III.—Series III also consisted of four rows—Nos. 3, 6, 9 and 12. This series was not sprayed at all with bordeaux mixture and only once (July 11) with poison, consisting of eight ounces of "green arsenoid" in 50 gallons of dilute lime water. There were so few "bugs" that the average farmer would have considered it unnecessary to apply poison.

THE RESULTS OF THE EXPERIMENTS.

AS INDICATED BY THE CONDITION OF THE FOLIAGE.

At Geneva.—Potato "bugs" did no appreciable damage to any of the plats. Twice they appeared in large numbers, but were promptly killed before they did any damage, and thus their ravages were practically eliminated from the experiment.

A few "bugs" were observed at the time of the first spraying of series II (June 25), but it was not thought necessary to poison them. They first appeared in destructive numbers about July 9. On that date it was found that many colonies had hatched and were just commencing to feed. On this account the entire field was treated on July 10. On series I and II the paris green was added to the bordeaux, and on series III it was used alone in lime water. The "bugs" were nearly all killed. On July 15 the only living "bugs" which could be found were a few full-grown beetles. The old ones appear to be more difficult to poison.

As late as July 23 only an occasional "bug" could be found, but on July 25 a new brood began to hatch, and it was observed that they were nearly all on the rows of series III, which had not been sprayed with bordeaux. In view of the fact that the paris green applied on July 10 had killed the "bugs" about equally well on all three plats, it is worthy of note that the new brood appeared almost entirely on series III. It appears that the old beetles shunned the plants covered with bordeaux and laid their eggs only on the unsprayed rows.

On July 30 the "bugs" were so numerous on the unsprayed rows that they would soon have done much damage unless killed, and hence it was necessary to treat series III a second time with
paris green in lime water. As there were no "bugs" on the other two series, no paris green was used on them, but series II was sprayed for blight with bordeaux alone. The treatment for "bugs" on series III was effective. They were nearly all dead the following day and there was no further trouble from "bugs" during the remainder of the season.

The punctures of flea-beetles⁵ were fairly abundant as early as July 10, but little damage was done by these insects until toward the close of August, at which time they attacked the unsprayed rows and hastened, somewhat, the death of the plants. The sprayed rows were practically free from flea-beetle injury.

The plants suffered neither from drought nor from wet weather, and there was no early blight, *Alternaria solani*. Late blight, *Phytophthora infestans*, first appeared on the unsprayed rows July 28, but made slow progress. On August 25 the unsprayed rows began to look a little brown, as viewed by one standing at the end of the field. Upon entering the field and making a closer examination it was found that the unsprayed plants had a trimmed-up appearance, due to the death of many of the lower leaves. There were also some yellow leaves. At the same time the foliage on the sprayed rows was practically perfect, there being only occasionally a blighted leaf. The lower leaves, clear to the ground, were alive and perfect and none yellow. The color of the sprayed plants was a darker green than that of the unsprayed plants. There was, apparently, no difference between the plants sprayed three times and those sprayed every two weeks.

During the last week in August the unsprayed plants deteriorated rapidly and the contrast in appearance between the sprayed and unsprayed rows became marked. This was due to the combined attacks of late blight and flea-beetles. However, as late as August 28, one month after the first appearance of blight, scarcely any of the plants had died, although they commenced to die very soon after that date.

On September 4 the contrast between the sprayed and unsprayed rows was very marked. Many unsprayed plants were

⁵ *Crepidodera cucumeris.*
entirely dead, while on many more one-third to one-half of the foliage was dead, and all of the plants had lost their lower leaves. For the first time there now appeared to be a slight difference between the rows of series I (sprayed three times) and those of series II (sprayed every two weeks). The latter were still almost perfect in foliage, while the former showed a considerable number of blighted leaves and also some yellow leaves.

On September 10 practically all of the unsprayed plants were dead. A few plants still had a few green leaves at their tips. Both sprayed series now showed many leaves browned at the tips, and there was somewhat more of this on series II than on series I. Microscopic examination showed that this tip browning was chiefly due to some other cause than *Phytophthora*. In the majority of cases no *Phytophthora* could be found. Only a few dead stalks were found on the sprayed rows.

An interesting observation made at this time was that stalks from the sprayed rows lopping over to the ground in the direction of the adjacent unsprayed row were usually dead; whereas stalks from the same row: lopping on the ground in the opposite direction, toward a sprayed row, were still green.

By September 16 the plants on series I and II had commenced to die. Many stalks were brown and on almost every hill there were indications that growth was nearly ended.

By September 22 the unsprayed plants were all dead and their stems mostly dry. On the sprayed rows about 25 per ct. of the plants still had sufficient foliage to enable them to make some growth, but this date is to be considered as practically the close of the growing period for series I and II. The difference between the two series was so slight as to seem unimportant.

On all of the unsprayed rows, and on the sprayed rows as well, the plants died very irregularly, some earlier and some later, making it difficult to determine the exact time at which the plat as a whole was to be considered dead. Hence it was difficult to determine exactly how much the sprayed plants outlived the unsprayed plants. However, it may be said that the sprayed plants were in somewhat better condition on September 22 than the unsprayed plants were on September 10, making the period of growth for the sprayed plants at least twelve, and probably four-
teen, days longer than that of the unsprayed plants. It should also be noted that the sprayed plants were in almost full foliage until within a short time of their death, and were thus able to assimilate at their full capacity throughout the greater part of their life. The unsprayed plants, on the contrary, lost many of their leaves early in the season and their power of assimilation was greatly decreased.

At Riverhead.—In the experiment at Riverhead, "bugs" gave practically no trouble. There were only traces of early blight and no late blight. Nevertheless, the sprayed plants lived several days longer than the unsprayed plants. This is owing to the fact that flea beetles were rather plentiful at times and injured the unsprayed plants most.

On August 11 the contrast in color between the sprayed and unsprayed rows was so marked that it could be plainly seen at a distance of one-half mile. At this date, there was still a little green foliage on series I, sprayed three times, and on some of the plants the tubers were probably growing a little. Only a few stalks were dead and dry.

On series II, sprayed seven times, about one-third of the foliage was yet alive and the tubers must have been growing considerably. The lower leaves were mostly dead, but plants entirely dead were rare. While the plants on this series were considerably injured by flea beetles, they were not nearly as bad as the plants on series I, sprayed three times, or on series III, unsprayed. A considerable portion of the increased yield on series II is attributable to better protection against flea beetles. At the same time, the plants on series III, unsprayed, were all dead and about forty per ct. of the stems were dry.

As shown by the yield.

At Geneva.—The potatoes were dug on September 26, 27 and 30. At that time the majority of the stems on the sprayed rows were still succulent, but growth had ceased except in an occasional plant. The unsprayed plants were all dead and the stems dry.

The potatoes were dug by hand and care taken to lose none. The product of each row was sorted into two grades, mar-
ketable tubers and culls; and the weight of each grade taken. All tubers larger than a hen’s egg were graded as marketable. The sorting was nearly all done by the writers and as uniformly as possible.

**Table I. Yields in the Experiment at Geneva.**

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<tr>
<th>Section</th>
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<th>Treatment</th>
<th>Yield per row</th>
<th>Yield per acre</th>
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<td>2.</td>
<td>Sprayed 7 times.</td>
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<td>31 6</td>
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<td>3.</td>
<td>Unsprayed.</td>
<td>427 2</td>
<td>25 8</td>
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<td>282 14</td>
<td>29 8</td>
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<tr>
<td>B.</td>
<td>4.</td>
<td>Sprayed 3 times.</td>
<td>394 14</td>
<td>26 14</td>
</tr>
<tr>
<td></td>
<td>5.</td>
<td>Sprayed 7 times.</td>
<td>411 8</td>
<td>26 9</td>
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<td></td>
<td>6.</td>
<td>Unsprayed.</td>
<td>250 9</td>
<td>35 0</td>
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<tr>
<td>C.</td>
<td>7.</td>
<td>Sprayed 3 times.</td>
<td>360 2</td>
<td>29 12</td>
</tr>
<tr>
<td></td>
<td>8.</td>
<td>Sprayed 7 times.</td>
<td>413 3</td>
<td>25 9</td>
</tr>
<tr>
<td></td>
<td>9.</td>
<td>Unsprayed.</td>
<td>271 11</td>
<td>26 10</td>
</tr>
<tr>
<td>D.</td>
<td>10.</td>
<td>Sprayed 3 times.</td>
<td>427 8</td>
<td>15 0</td>
</tr>
<tr>
<td></td>
<td>11.</td>
<td>Sprayed 7 times.</td>
<td>389 13</td>
<td>21 1</td>
</tr>
<tr>
<td></td>
<td>12.</td>
<td>Unsprayed.</td>
<td>276 8</td>
<td>32 2</td>
</tr>
<tr>
<td>E.</td>
<td>13.</td>
<td>Sprayed 3 times.</td>
<td>360 13</td>
<td>20 4</td>
</tr>
<tr>
<td></td>
<td>14.</td>
<td>Sprayed 7 times.</td>
<td>392 11</td>
<td>22 2</td>
</tr>
<tr>
<td></td>
<td>15.</td>
<td>Unsprayed.</td>
<td>246 7</td>
<td>30 10</td>
</tr>
</tbody>
</table>

*Comments on the table.—* An examination of the above table reveals the following: (1) In each of the five sections the sprayed rows yielded more than the unsprayed row, the least difference being in section C, where the three-sprayed row 7 yielded only 74 bushels per acre more than the unsprayed row 9. The greatest difference between a three-sprayed row and an unsprayed row in any one section (barring section D, in which there is evidently an error) is in section B, where row 4 yielded 120.4 bushels per acre more than row 6.

(2) In every case, except in section D, the seven-sprayed row yielded more than the adjacent three-sprayed row in the same section, the difference being least in section B, where it was 14

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6 It will be observed that row 10 (sprayed 3 times) yielded at the rate of 214 bu. per acre more than row 11 (sprayed 7 times.) There is surely some error here, but it has been impossible to account for it. It is not in the weighing. Because of this discrepancy it will be necessary to leave section D, comprising rows 10, 11 and 12, out of consideration in making up the average yields.
bushels per acre, and greatest in section C, where it was 44 bushels per acre.

(3) The yield of rows receiving the same treatment varied considerably in different portions of the field. With the unsprayed rows the greatest difference was 30 bushels per acre; with the three-sprayed rows, 29 bushels; and with the seven-sprayed rows, 29 bushels. These differences seem to have been due chiefly to differences in severity of attack by blight. The blight started in section E next an oat field which bordered the potato field on one side for about one-half its length. The damage done by blight was noticeably greater here than in any other part of the field.

Yield by series.—The four rows sprayed three times constitute series I, and the average yield of these four rows make the yield of series I. The yields given for series II and III were computed in the same manner. The yield by series is shown in the following table, in which the results of the experiment are reduced to their simplest terms.

Table II. Yield by Series at Geneva.

<table>
<thead>
<tr>
<th>Series</th>
<th>Rows</th>
<th>Dates of spraying</th>
<th>Yield per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1, 4, 7 and 13</td>
<td>July 10, 23 and Aug. 12</td>
<td>Bu 317 lbs. 41</td>
</tr>
<tr>
<td>II</td>
<td>2, 5, 8 and 14</td>
<td>June 25, July 10, 23, 30, Aug. 12, 26 and Sept. 10</td>
<td>342 36</td>
</tr>
<tr>
<td>III</td>
<td>3, 6, 9 and 15</td>
<td>Not sprayed</td>
<td>219 4</td>
</tr>
</tbody>
</table>

Increase in yield due to spraying three times, 98 I-2 bushels per acre.

Increase in yield due to spraying seven times, 123 I-2 bushels per acre.

Considering that the difference in the appearance of the foliage on series I and II was very slight, we were surprised to find the difference in yield so large as 25 bushels per acre.

The loss from rot.—Although there had been considerable late blight (Phytophthora) on all of the unsprayed rows and a little also on the sprayed rows, the tubers were found to be but little affected with rot. On the sprayed rows only an occasional rot-

7 Rows of Section D omitted because of manifest error.
ten tuber was found, and even on the unsprayed rows the number was not large. Most of the affected tubers were completely rotten. Very few showed the early stages of the disease.

In order to determine, approximately, the amount of the loss from rot, the number of rotten tubers was counted on row 12, an unsprayed row which probably suffered as much from blight as any other row in the field except row 15. The number of rotten tubers was found to be 134. Unfortunately, the number of sound tubers in row 12 was not determined, but assuming it to be the same as on the unsprayed row 6, where the number was 1,628, the loss from rot was 7.6 per ct. In size the rotten tubers appeared to average about the same as the sound ones. This would make the loss from rot on the unsprayed rows about 18 bushels per acre, which is small, considering that the tops were so badly blighted. Had the conditions been more favorable for rot it is likely that the difference in yield between the sprayed and unsprayed series would have been considerably greater.

At Riverhead.—The potatoes were dug on August 29 and 30 by hand and carefully and uniformly sorted into marketable tubers and culls. On the sprayed rows growth had ceased, the leaves being nearly all dead, but many of the stems were still green and more or less succulent. The unsprayed plants were entirely dead and the stems dry.

<table>
<thead>
<tr>
<th>Table III. Yields in the Experiment at Riverhead.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>B.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>C.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Comments on the table.—The most notable feature of this table, as compared with the table of yields for Geneva on page 249, is the smaller difference in yield between sprayed and unsprayed rows. This is due to the fact that in the experiment at Geneva late blight and rot wrought considerable havoc among the unsprayed plants, while in the experiment at Riverhead there was no attack of late blight. At Riverhead the increased yield of the sprayed rows was chiefly due to better protection against flea beetles and to the stimulating effect of bordeaux on the foliage. There was no disease to combat in this experiment except, perhaps, a small amount of early blight.

In section C, row 8, sprayed three times, yielded at the rate of 20 bushels per acre more than row 7, sprayed seven times. In section D, row 12, unsprayed, yielded eight bushels per acre more than row 11, sprayed three times. These are plainly inconsistencies which we are unable to explain. Possibly they are due to errors in weighing, but we think not. Great care was exercised to give the rows an equal chance in every respect except in the matter of spraying, but, somehow, error crept in. This is an illustration of the inaccuracies which may occur even in the most carefully planned and carefully managed field experiments.

Yield by series.—The yield by series is shown in the following table:

<table>
<thead>
<tr>
<th>Series</th>
<th>Rows</th>
<th>Dates of spraying</th>
<th>Yield per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2, 5, 8 and 11</td>
<td>May 26, June 20 and July 22</td>
<td>295 Bu., 20 lbs.</td>
</tr>
<tr>
<td>II</td>
<td>1, 4, 7 and 10</td>
<td>May 26, June 3, 20, 30, July 11, 23 and August 5.</td>
<td>312 Bu., 35 lbs.</td>
</tr>
<tr>
<td>III</td>
<td>3, 6, 9 and 12</td>
<td>Not sprayed</td>
<td>267 Bu., 40 lbs.</td>
</tr>
</tbody>
</table>

Increase in yield due to spraying three times, 27 2-3 bushels per acre.
Increase in yield due to spraying seven times, 45 bushels per acre.
Loss from rot.—At Riverhead there was no loss from rot, not even on the unsprayed rows.
With the potato the question of quality is less important than with many other vegetables and fruits. For the most part, potatoes are potatoes so far as their food value and cooking qualities are concerned, although it is true that some varieties are recognized as being preferable to others in these respects; also, tubers grown in certain localities where the soil is supposed to be especially suited to the potato command a somewhat higher price. For a given variety buyers usually have a uniform price, except for lots in which the tubers are scabby or much out of the ordinary size. In short, sprayed potatoes sell for the same price as unsprayed ones, because consumers recognize no difference between them.

As for the effect of spraying on the quality of the tubers, it appears to be simply a question of maturity. When a potato plant dies prematurely from blight its tubers must of necessity be less mature than those of sprayed plants which grew two or three weeks longer. The difference in the degree of maturity between the tubers of sprayed and unsprayed plants depends, of course, upon the length of time the life of the plants is prolonged by spraying. In those cases in which the unsprayed plants are killed early in the season, while the sprayed ones grow on to the close of the season and die naturally, it seems as if the difference in the maturity of the tubers might be sufficiently great to materially affect their food value. In order to get light on this subject it was suggested by Director Jordan that a chemical analysis be made of tubers from sprayed and unsprayed plants in the experiment at Geneva.

Accordingly, there were taken fifty consecutive hills from a row sprayed seven times (row 8) and fifty other hills from the adjoining unsprayed row (row 9) and the entire product placed at the disposal of Director Jordan, under whose direction the analyses were made. Following is Dr. Jordan's account of the results:

"As stated in the foregoing, there was placed in my hands the product of fifty hills of potatoes sprayed seven times and of fifty hills unsprayed. Both lots were weighed, counted and analyzed. The results appear in the following table:
CHARACTER AND COMPOSITION OF SPRAYED AND UNSPRAYED POTATOES.

YIELD AND SIZE OF TUBERS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of Tubers in 50 Hills</th>
<th>Tubers in one hill</th>
<th>Total weight of tubers</th>
<th>Average weight of tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayed potatoes</td>
<td>345</td>
<td>78</td>
<td>423</td>
<td>8.46</td>
</tr>
<tr>
<td>Unsprayed</td>
<td>263</td>
<td>79</td>
<td>342</td>
<td>6.84</td>
</tr>
</tbody>
</table>

COMPOSITION OF TUBERS.

<table>
<thead>
<tr>
<th>Lab. No.</th>
<th>Treatment</th>
<th>Water</th>
<th>Dry Matter</th>
<th>Ash</th>
<th>Protein</th>
<th>Nitrogen free compounds</th>
<th>Starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1343</td>
<td>Sprayed potatoes</td>
<td>76.</td>
<td>24.</td>
<td>.9</td>
<td>2.2</td>
<td>20.9</td>
<td>16.9</td>
</tr>
<tr>
<td>1344</td>
<td>Unsprayed</td>
<td>77.4</td>
<td>22.6</td>
<td>.9</td>
<td>2.4</td>
<td>19.3</td>
<td>15.8</td>
</tr>
</tbody>
</table>

"These data disclose the following facts:

"(1) The sprayed potatoes yielded more tubers to the hill and of larger average size than the unsprayed.

"(2) Spraying apparently had the effect of increasing the dry matter of the tubers. This increase is seen to consist mostly of starch, the excess of dry matter in the tubers from sprayed potatoes being 1.4 per ct., and of starch 1.1 per ct.

"Other things being equal, the food value of a vegetable or fruit is proportional to its digestible dry matter. As the increase from spraying is seen to be almost wholly starch, and as this carbohydrate is practically all digested, it is reasonable to conclude that the sprayed potatoes are about 7 per ct. more valuable for human food than the unsprayed.

"For the same reasons and to the same extent the sprayed potatoes would be worth more to manufacturers of starch."

THE PROFIT.

At Geneva.—For the reasons given on page 238 no attempt was made to keep an account of the expense of spraying in the experiment. Nevertheless, it is worth while to consider briefly the probable profit.
In central and western New York the market price of potatoes during October was about 50 cents per bushel. Early in November the experiment potatoes were actually sold for 60 cents per bushel. Spraying three times increased the yield 98½ bushels per acre. At 50 cents per bushel this increase is worth $49.25. Judging from previous experience, it is our opinion that spraying as thorough as in this experiment could be done on a commercial basis at an expense not greater than $2 per acre for each spraying, or $6 for three sprayings. This allowance is certainly ample. On Long Island, in 1896, the Station sprayed eight acres of potatoes at a total expense of 80 cents per acre for each application; but, of course, the work was not done as thoroughly as at Geneva. Under proper management and with a supply of water reasonably accessible, potatoes may be sprayed at a total expense of $1 per acre for each application. Besides, it should not be forgotten that at least one, and usually two, applications of poison are required to keep the Colorado potato beetles, or "bugs," under control. In this particular experiment it was necessary to use Paris green twice on the unsprayed rows to kill "bugs." Probably this could not have been well done for less than 50 cents per acre for each application, or $1 per acre for two applications. In fairness, this $1 should be deducted from the $6, leaving $5 as the extra expense per acre due to spraying.

The increase in yield per acre due to seven sprayings was 123½ bushels, having a value of $61.75. Allowing that the extra expense of the seven sprayings was $13 per acre, there is left a net profit of $48.75 per acre.

At Riverhead.—In the experiment at Riverhead the Station had an agreement with Mr. Surrine to pay him for all expense of the spraying, labor being rated at 20 cents per hour. Mr. Surrine's bill for labor and chemicals was $2.42 for the three sprayings of series I and seven sprayings of series II, making the actual expense of spraying $2.42 per acre for each application. Of course this expense is proportionally higher than it would be where fields of several acres are sprayed with a horse sprayer. As already stated, $2 per acre is ample allowance for the expense of spraying as thoroughly as was done in these experiments.

8 See Bul. No. 123 of this Station, page 241.
On Long Island the price of potatoes during September, the month in which the principal part of the crop of late potatoes is dug, ranged from 25 to 55 cents per bushel. The experiment potatoes were stored and actually sold in December for 65 and 75 cents per bushel. The increase in yield per acre due to three sprayings was $27\frac{3}{4}$ bushels, worth, at 40 cents per bushel, $\$11$. Deducting from this the sum of $\$6$, the expense of the three sprayings, there is left a net profit of $\$5$ per acre.

The increase in yield per acre due to seven sprayings was 45 bushels, worth $\$18$. Deducting $\$14$ as the expense of the seven sprayings, there is left a net profit of $\$4$ per acre.

**CONDITION OF THE POTATO CROP IN NEW YORK IN 1902.**

In central and western New York the potato crop of 1902 was light. Prolonged wet weather delayed planting, and many fields afterward suffered from an excess of rain. The rains also hindered cultivation. Early varieties blighted and rotted badly during the latter part of July, making it necessary to dig and market them at once. Late potatoes became quite generally affected with late blight during the last week in July and the first week in August, and many fields were entirely dead by September 1.

During August and September the weather was drier than in July and much less favorable to blight. In fact, after about August 10 the weather was such that it is unlikely that blight would have done any appreciable damage had it not been that the fields were already thoroughly seeded with the disease. As it was, the foliage of all unsprayed potatoes was considerably injured by late blight, but there was only a slight amount of rot found among the tubers at digging time.

From all sections, except Long Island, small yields were reported. In the vicinity of Geneva yields as high as 100 bushels per acre were rare. From 50 to 75 bushels per acre were the common yields, while yields as low as 25 bushels per acre were frequently reported and occasionally fields were found not worth digging.
In the central and western portions of the State it appears that late blight and "bugs" were practically the only troubles of potato foliage. There was no early blight and flea-beetles did only slight damage late in the season. In some sections "bugs" were reported unusually troublesome. Many farmers found it almost impossible to kill them with paris green in water. Some used it at the rate of two or three pounds to 50 gallons of water, making two or three applications; and even then the bugs did much damage. Such heavy applications of paris green are likely to have injured the foliage unless lime water was used with it.

On Long Island, particularly in the eastern portion, the potato crop was unusually heavy. In the western portion there was a little blight and rot, while in the eastern portion there was no late blight worth mentioning, very little early blight, and "bugs" were about as troublesome as usual. Flea-beetles and tip burn did some damage. Yields of 300 bushels per acre were very common, while yields of 350 to 400 bushels per acre were occasionally reported.

**CAN FARMERS OBTAIN AS GOOD RESULTS?**

Some persons are inclined to question the reliability of the results obtained in potato spraying experiments like those reported in this bulletin. They doubt that such results can be duplicated in ordinary farm practice. It cannot be denied that such doubts are, to a certain extent, justified, and, therefore, it is worth while to devote some space to a discussion of this subject.

In the experiment at Geneva the yields obtained were so far above those obtained by farmers in the surrounding country as to arouse curiosity concerning the methods of culture employed. On this account the methods have been given in full on page 241. Even on the unsprayed rows the average yield per acre was 219 bushels, or about double the best yields obtained by farmers in the vicinity. In seeking to account for this large yield on unsprayed rows several have called attention to the fact that fertilizer was used at the rate of 1,000 pounds per acre, and expressed the opinion that this quantity was excessive and larger than a farmer could afford to use. On many farms, already rich in fer-
tility, it would no doubt be wasteful to apply fertilizer at the rate of 1,000 pounds per acre for a potato crop; but in the experiment at Geneva the condition of the land was such that the application of that quantity seemed justified. By a fortunate accident it was made possible to determine accurately the benefit obtained from the use of the fertilizer. In weighing out fertilizer for the experiment, the two outside rows, O. A and O. B (see diagram on page 240) were forgotten and no allowance of fertilizer made for them. The result was that these two rows were planted without fertilizer. Throughout the season they were treated in exactly the same manner as the unsprayed rows in the experiment. They received no bordeaux mixture, but were treated with paris green for "bugs" at the same time as the unsprayed rows. When the potatoes were dug row O. A, without fertilizer, yielded at the rate of 137 bushels per acre, while the nearest unsprayed row, row 3, with fertilizer, yielded at the rate of 235 bushels per acre. On the other side of the field, row O. B, without fertilizer, yielded 100 bushels per acre; while the neighboring unsprayed row, row 15, with fertilizer, yielded 205 bushels per acre. Thus it appears that the use of 1,000 pounds of fertilizer per acre increased the yield about 100 bushels per acre. The value of the fertilizer used was $13, while 100 bushels of potatoes were worth $50, and the net profit from the use of the fertilizer was $37 per acre. Certainly it would have been false economy not to have used the fertilizer.

As for the experiment at Riverhead, where fertilizer was used at the rate of 1,100 pounds per acre, it need only be said that on Long Island that quantity is considered moderate, and Station experiments have shown 1,000 pounds per acre to be profitable. Many potato growers use one ton per acre and believe that it is profitable.

Another objection raised by potato growers in central and western New York is that the potatoes were planted in drills, which, of course, tends to increase the yield, but on many farms is impractical owing to the difficulty of keeping the crop free from weeds. Many farmers plant from 33 to 36 inches apart each way, which admits of horse cultivation in both directions.

9 Bulletin Nos. 93, 112, 137, 154 and 187 of this Station.
On land foul with weeds it would probably be unwise to plant in drills; for, no doubt, considerable hand labor would be required, especially in wet seasons. However, it should be the aim to prevent land from becoming foul. On the Station farm it is the policy to keep weeds under control, and, consequently, no difficulty whatever was experienced in keeping the potatoes clean by ordinary horse cultivation.

We do not consider the objection to planting in drills well founded. By a little extra care, year after year, weeds may be kept under control to such an extent that it will be possible to plant potatoes in drills and keep them free from weeds without employing hand labor. Where potatoes can be planted in drills it is desirable to do so, since the yield can be greatly increased thereby at little extra expense.

As to the use of whole small tubers for seed little need be said. The object was to secure a full stand in order to have uniform conditions throughout the experiment; and a full stand is more readily obtained with whole tubers than with pieces. However, it is not generally considered a good practice to plant whole small tubers.

Another objection is the small scale upon which the experiment was made. Each series had an area of one-tenth acre and each row one-fiftieth acre. There is every reason to believe that the yields were actually as large as stated. The product of each row was accurately weighed to an ounce and the land accurately measured. But it must be admitted that so small an area has advantages over large ones. In the first place, almost every large field has a certain amount of poor or waste land which cuts down the average yield; whereas, a small field can be so located that there will be no waste land. Secondly, with a small field it is possible to plant, spray, cultivate, etc., always at the proper time, which is not possible for large fields.

The spraying was done more thoroughly than most farmers would do it, and since the success of spraying depends largely upon the thoroughness with which it is done, it is likely that the benefits from spraying in the experiment were greater than they would be from spraying done by the average farmer. However, the thoroughness of spraying was partially offset by the fact that
the diseased foliage of unsprayed rows often intermingled with
the foliage of sprayed rows, subjecting them to greater danger
of infection than would be the case where a whole field is sprayed.
Also, the alternation of sprayed with unsprayed rows made the
progress of the disease less rapid among the unsprayed plants
than it would have been in unsprayed fields, where the disease
could pass from one plant to another across rows as well as
lengthwise of them. In the experiment infection among the un-
sprayed plants must have spread chiefly lengthwise the rows.

No matter in what way a large yield is brought about, whether
by the use of large quantities of fertilizer, by thick planting, extra
cultivation or the use of productive varieties, the benefits from
spraying will be correspondingly increased. That is to say, a
field of potatoes which without spraying would yield but 100
bushels per acre, would not give as large returns for spraying as
would a field capable of producing 200 bushels per acre without
spraying. In the Geneva experiment, with potatoes which
yielded 219 bushels per acre without spraying, three sprayings
increased the yield 98 1/2 bushels per acre. Had these same three
sprayings been applied to fields near Geneva which yielded only
100 bushels per acre without spraying, it is unlikely that the yield
would have been increased as much as 98 1/2 bushels per acre; but
just how large an increase might be expected in such a case is
not clear\(^\text{10}\). Of course much depends on the cause of the low

\(^{10}\) The best information on this subject available is furnished by a farmer living
about five miles northwest of Geneva. He sprayed 12 acres of potatoes three times
with a power sprayer which sprayed five rows at a time with one nozzle per row.
One row through the center of the field was left unsprayed. This row was dug
separately and the yield carefully measured. The same was done with an adjacent
sprayed row. It was found that the sprayed row outyielded the unsprayed row by
a trifle more than three bushels. Since sixteen rows were required to make an acre,
the increase in yield amounted to over 48 bushels per acre. The yield on the
unsprayed row was at the rate of 110 bushels per acre and on the remainder of the
field about 160 bushels per acre. He estimates that on the twelve acres spraying
increased the yield by nearly 600 bushels of potatoes having a value of $300. Of
this sum at least $235 was clear profit.

In this case the spraying could not have been thoroughly done and consequently
the results are not strictly comparable with those obtained in the experiment on the
Station farm; but they show what can be done by farmers under average conditions.
Unquestionably, there are hundreds of farmers in central and western New York
who could have made $20 per acre net profit by spraying their potatoes last season.
yield. If it were chiefly due to the ravages of insects or blight the case would be quite different from what it would be if there were errors in culture or a lack of fertility. Spraying cannot be expected to correct errors in culture or take the place of fertility.

With the ravages of blight and insects the same, it seems probable that the maximum benefit from spraying is to be obtained in potato fields in which all other conditions are most favorable to a large yield.

While an increase of 98 1/2 bushels per acre is to be considered an excellent return for three sprayings, the amount is not as great as it might have been had the blight been as severe in the experiment field as it was in many other fields around Geneva. In some respects the conditions for getting large returns were exceptionally good in the experiment, but on the whole it seems as if up-to-date potato growers, who employ correct cultural methods, fertilize liberally and spray properly, should have done equally well during the past season.

**DOES IT PAY TO SPRAY POTATOES?**

To give a positive answer to this question would be to anticipate the results of the long series of spraying experiments just begun by the Station. However, it may be said that the writers, themselves, already have decided opinions on the subject. The object of the experiments is to produce evidence which shall be so conclusive that farmers generally will be convinced and practice spraying.

It is our opinion that it *does* pay well to spray potatoes. In some seasons it pays much better than in others, but, if properly managed, it will not result in loss in any season. Many persons think that spraying is useful only in preventing blight and rot. This is a mistake. Numerous experiments show that spraying increases the yield considerably even when the plants are not attacked by blight. Bordeaux mixture stimulates the potato leaves to produce more starch. Then too, it has been shown that "bugs" and flea-beetles are kept more thoroughly under control by spraying with bordeaux mixture than by any other method. Farmers certainly do not realize how great is the damage done by "bugs" and flea-beetles. The common methods of fighting
these insects are not as effective as they should be. For the most part flea-beetles go unchecked. "Bugs" are poisoned with paris green, which is either applied in dry form by means of a powder gun or in water by means of a sprinkler. By either method a large proportion of the "bugs" usually escape and the plants are more or less stripped of their leaves. In many cases the paris green treatment is applied two or three times and large quantities of the poison used. Still the "bugs" thrive, while the foliage is often seriously injured by the paris green. Paris green applied dry almost always does some injury to the foliage. The same thing often happens when it is used in pure water, but when it is used in lime water the foliage is not injured. Of course "bugs" can be thoroughly controlled with paris green, but as a matter of fact they usually are not controlled, and considerable damage results.

When potatoes are sprayed three times or more with bordeaux mixture there is no trouble with "bugs," no damage done by them, and there is no paris green injury to the foliage. All that is necessary is to add paris green to the bordeaux at the rate of one-half to three-fourths of a pound to each 50 gallons of bordeaux. Spraying also prevents a considerable part of the damage done by flea-beetles. They are not entirely controlled, but their ravages are materially lessened. Thus, spraying obviates the necessity of fighting "bugs" and flea-beetles.

Fairly thorough spraying can be done at a total expense of $1 per acre for each application. At this rate three sprayings would cost $3. The returns which may be expected from such spraying are 25 to 100 bushels per acre increase in yield. In any season the increased yield will cover the expense of spraying, and in most seasons there will be a large net profit.

DIRECTIONS FOR SPRAYING.

Commence spraying when the plants are six to eight inches high and repeat the treatment at intervals of about two weeks as long as the plants continue green. Usually six applications will be required. The bordeaux mixture should contain six pounds of copper sulphate to each 50 gallons. Whenever "bugs" or flea-beetles are plentiful add paris green at the rate of one-half
to three-fourths pound to 50 gallons of bordeaux. Thoroughness of application is to be desired at all times, but is especially important when flea-beetles are numerous or the weather favorable to blight. When a horse sprayer is used there should be two nozzles for each row.

Those who wish to get along with three sprayings should postpone the first one until there is danger of injury from "bugs" or flea-beetles, and then spray thoroughly with bordeaux and paris green. The other two sprayings should likewise be thorough and applied at such times as to keep the foliage protected as much as possible during the remainder of the season. Very satisfactory results can be obtained from three sprayings.

A single spraying is far better than none and will always be profitable, but more are better. There is no excuse for using paris green alone for "bugs." Whenever it is necessary to fight insects use bordeaux containing paris green.