EFFECT OF CERTAIN ARSENITES ON POTATO FOLIAGE.

W. H. JORDAN, F. C. STEWART AND H. J. EUSTACE.
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W. H. JORDAN, F. C. STEWART AND H. J. EUSTACE.

SUMMARY.

This bulletin gives an account of some experiments designed to determine to what extent and in what manner paris green and arsenite of lime are injurious to potato foliage.

In an experiment with paris green this well known insecticide was applied four times by three common methods: viz., with water, with lime water and with bordeaux. Other rows received bordeaux only while still others were left untreated for a check.

At no time during the experiment, not even when the paris green was applied at the rate of 4½ lbs. per acre, was there any indication of injury to the foliage. On the contrary, the rows receiving paris green in water and also those treated with paris green in lime water were conspicuously more perfect in foliage than were the check rows. This difference was due to the partial prevention of late blight. It was shown conclusively that paris green has considerable value as a fungicide—at least one-third as much as bordeaux. Rows treated with paris green in water outyielded the check rows by 46 bu. per acre.

Rows treated with paris green in lime water yielded 12 bu. per acre less than those receiving paris green in water; but it is possible that this difference was the result of natural variation and not due to the lime.
Rows receiving paris green in bordeaux gave slightly larger yield than rows receiving bordeaux only.

In an experiment with arsenite of lime, arsenite of soda stock solution prepared by the Kedzie formula was applied with lime water and also with bordeaux. In lime water it injured the foliage severely although two pounds of quick lime were used for each pint of the stock solution; but in bordeaux mixture containing the same quantity of arsenite of soda solution and of lime there was no apparent injury. It is clear that arsenite of soda may be much more safely used with bordeaux than with lime water.

Rows treated with bordeaux alone outyielded rows treated with arsenite of soda in bordeaux by 34 bu. per acre. This suggests that the arsenite of soda may have been harmful although not showing any effect on the foliage. However, this is very doubtful. There is good reason to believe that, in this experiment, the foliage indications are more reliable than the yields.

The chief conclusions reached are:

1. That paris green is not injurious to potato foliage if applied in moderate quantity with lime water or bordeaux mixture evenly distributed;

2. That paris green has considerable fungicidal value;

3. That arsenite of soda should not be applied to potatoes except with bordeaux mixture.
INTRODUCTION.

Certain arsenical preparations, when used as insecticides, bear an important relation to crop production in the United States. It is unquestionably true that many farm and orchard crops could not now be successfully grown in a great majority of years without some means of preventing the ravages of insect pests. This is especially true of the potato crop, because of the depredations of the Colorado beetle. That serious harm from this pest can be prevented by the use of certain arsenical compounds has been demonstrated beyond question; and when we remember that approximately 400,000 acres of potatoes are annually grown in New York, having a value of nearly $16,000,000, we realize the important place that paris green and other insecticidal preparations occupy in our farm practice.

Very much has been said in a vague way about the injuries to potatoes and other crops from the application to their foliage of arsenical compounds. Undoubtedly such injuries have occurred in many instances but whether these have been occasioned by an unavoidable effect of the arsenic compounds or whether they have been due to a misuse or injudicious application of these compounds is not always clear. Within quite recent years it has been freely claimed on the part of some writers and speakers that paris green is a substance which may not be safely applied to the potato plant. There is a somewhat justifiable suspicion that these claims have not always been entirely impartial but that they have been made to some extent in the interests of non-arsenical preparations. It is worth while to determine, as a fundamental fact, whether, when properly used, paris green and other arsenic compounds are in any way deleterious to the potato plant. It is scarcely a good argument to say that this material is unsafe for use because it may be misused by unintelligent or careless farmers. There are very many utilities which would be excluded from the farm if they were to be discarded on the basis of possible misuse. The real question is, then, does paris green do the potato plant any injury when applied under proper conditions?
The experiments, the results of which are given in this bulletin, were planned with a view of studying this specific question. These results are interesting and so far as a single season's observations are concerned they are conclusive.

HISTORICAL.

PARIS GREEN.

The use of paris green as an insecticide dates from some time between 1860 and 1870, soon after the Colorado potato beetle became a destructive pest in the Western States.\(^1\) Exactly when and by whom it was first used is not known. It was early observed that some tender kinds of foliage were frequently injured by the paris green. In 1890, Gillette,\(^2\) at the Iowa Station discovered that this injury may be avoided by using the paris green with milk of lime, or, better still, with bordeaux mixture. In 1891, Kilgore\(^3\) at the North Carolina Station showed that the injury is due to soluble arsenic in the paris green; and that the value of lime as a preventive of the injury lies in its ability to change soluble arsenic into insoluble arsenite of lime. He also observed the insolvency of arsenites in bordeaux mixture and drew the conclusion: "That bordeaux mixture prevents the solubility of the arsenites and their injury to foliage by virtue of its lime." Weed\(^4\) at the Ohio Station had previously (in 1889) pointed out the desirability of combining insecticides with fungicides.

In recent years it has been very generally advised that paris green and other arsenical insecticides be not used alone but always in combination with milk of lime or with bordeaux mixture. Most fruit growers have now adopted this method, but

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many potato growers still persist in using paris green alone. The potato is less liable to arsenical injury than most other plants which require spraying; but it is an indisputable fact that the use of paris green on potatoes, as practiced by farmers, often results in serious injury to the foliage. Many cases of supposed blight are nothing but paris green injury. Jones of the Vermont Station was first to direct attention to this and give a detailed description of the symptoms of arsenical poisoning. He says:5

"The poisoning or 'burning' of potato leaves by improper applications of paris green is of more general occurrence than is commonly supposed and the resulting injuries are frequently attributed to the 'early blight' fungus. In cases of extremely strong applications of the paris green the leaves may be entirely killed or large areas 'burned' within a short time. Usually, however, its action is slower and longer continued. Its effects are then apparent as dead spots, black or brown in color, centering about flea-beetle punctures or other mutilations of the leaf. * * * These spots slowly continue to enlarge for some time and as a result of the slow death and drying of the tissues the surface of each spot is thrown into concentric elevations or ridges forming distinctly 'ringed spots.' * * * These spots so closely resemble those caused by the 'early blight' fungus that they are extremely deceptive." Continuing, he points out the symptoms by which early blight and arsenical poisoning may be distinguished. It should be noted that Jones attributes the injury to improper applications of paris green.

ARSENITE OF LIME.

Excepting paris green, the most popular insecticide for use on potatoes is white arsenic applied in the form of arsenite of lime. The insecticidal properties of white arsenic have been known for more than 50 years.6 In 1871 Saunders and Reed in Canada tested it on potatoes for the Colorado potato beetle. It was mixed with flour and applied dry. The results indicated that when

6 Lodeman, E. G. Loc. cit., p. 75.
applied sufficiently strong to kill the beetles it caused more or less injury to the foliage. Because of its caustic properties it was rarely used until after the publication of Kilgore’s formula in 1891. Kilgore recommended \(^8\) "boiling together for one-half hour in 2 to 5 gallons of water:

1 pound commercial white arsenic

2 " lime,

and diluting to required volume, say 100 gallons." In this way the arsenic is changed into insoluble arsenite of lime and made safer to use on foliage.

In 1897, Kedzie of the Michigan Agricultural College published what has come to be widely known as the ‘‘Kedzie’ formula.’’ It is essentially as follows:

White arsenic ........................................ 2 pounds.
Sal soda (washing soda) ......................... 8 "
Water ............................................... 2 gallons.

Boil 15 minutes or until the arsenic dissolves, leaving only a small quantity of muddy sediment. Replace the water lost in boiling. This makes a stock solution of arsenite of soda which may be placed in tightly stoppered jugs and kept on hand for use as needed. In preparing the spray mixture use two pounds of freshly-slaked lime with each pint of the stock solution in the desired quantity of water or bordeaux mixture. The arsenite of soda and the lime unite to form arsenite of lime. The arsenic in one pint of the stock solution is equivalent to four ounces of paris green.

The chief advantage of this formula over the one recommended by Kilgore is that the union of the arsenic and lime is more certainly accomplished.

Both the Kilgore and the Kedzie formulas are now used to a considerable extent. Prepared by either formula, white arsenic is a cheaper poison than paris green, quite as efficient and settles to the bottom of the spray tank less readily. For these reasons it is coming into popularity with orchardists and potato growers, although its use sometimes results in injury to the foliage.

\(^8\) Kilgore, B. W.  Loc. cit., p. 7.

\(^9\) Kedzie, R. C.  The M. A. C. Record, March 9, 1897.  A verbatim copy of this article may be found in Bulletin 152 of this Station, p. 300.
THE EXPERIMENT WITH PARIS GREEN.

PLAN AND METHODS.

The experiment included 25 rows of potatoes 290.4 feet long and three feet apart, each row having an area of one-fiftieth acre. The potatoes were of the variety Rural New Yorker No. 2. They were planted by hand May 27, 15 inches apart in the row. Each row received ten pounds of commercial fertilizer applied by hand as uniformly as possible in the furrows before planting. The potatoes came up uniformly and well making nearly a full stand of plants.

The 25 rows were divided into five series of five rows each and each series was sprayed in a different manner as follows:

  " II. " 2, 7, 12, 17, 22. Sprayed 4 times, paris green in water.
  " III. " 3, 8, 13, 18, 23. Sprayed 4 times, paris green in lime water.
  " IV. " 4, 9, 14, 19, 24. Sprayed 4 times with paris green in bordeaux and once with bordeaux alone.

The rows of Series I received no insecticide or fungicide of any kind. As soon as Colorado potato beetles appeared they were gathered by hand. Fortunately they were less numerous than usual, making it possible to control them completely by going over the plants every other day or, at most, once a day.

The paris green was invariably used at the rate of one pound to fifty gallons of water, lime water or bordeaux as the case might be. The spraying was done thoroughly and uniformly with a knapsack sprayer, always going over the plants twice,—out on one side of the row and back on the other.

First spraying.—The first spraying was made July 7. At this time the plants were 7 to 9 inches high, very vigorous and with foliage almost perfect. There were no flea-beetles and only a few colonies of newly-hatched Colorado potato beetles. Series II received paris green in water, one pound to fifty gallons; Series III, paris green in lime water prepared by mixing two pounds of freshly-slaked lime with 50 gallons of water and then adding one pound of paris green; Series IV, paris green in bordeaux at the rate of one pound to 50 gallons of bordeaux prepared by dissolv-
ing six pounds of copper sulphate in 50 gallons of water and adding lime slightly in excess of the quantity required to satisfy the yellow-prussiate-of-potash test; Series V, bordeaux only (some of the same lot as that used on Series IV, before adding paris green).

In this spraying, all mixtures were applied at the rate of 125 gallons per acre. The first rain following the spraying was a heavy shower on July 9.

Second spraying.—This spraying was made July 22. The plants were very thrifty. A few were showing blossoms. Much of the bordeaux had been washed off by rain and a large amount of new foliage had grown since the previous spraying. There were no flea-beetles. A few hills here and there were badly infested with Colorado potato beetles. Series II and III were treated exactly as in the first spraying. On Series IV and V the treatment was the same as in the first spraying except that the bordeaux was made by the 6-6-50 formula. All spray mixtures were applied at the rate of 125 gallons per acre.

In this spraying an error was made. Rows 8, 9, 10 and 11 were given the wrong treatment. This necessitates the rejection of these rows in making up the results of the experiment.

During the first night following the spraying it rained lightly all night, and on the day following there were showers alternating with periods of sunshine.

Third spraying.—The third spraying was made July 29. By this time the vines were so large that the branches of plants in adjacent rows touched. Potato beetles were well under control and there were no flea-beetles. Series II and III were again treated as in the first spraying, except that a larger quantity of spray mixture was used. On Series IV and V the treatment was the same as in the first spraying except that the bordeaux was made by the 6-4-50 formula.\textsuperscript{19} This time all spray mixtures were applied at the rate of 175 gallons per acre. On July 31 the rainfall was .02 inch and on August 1, .52 inch.

Fourth spraying.—This spraying was made August 12. The day being bright, the spray dried on the foliage quickly. The rows of Series I, II and III were much affected with late blight.

\textsuperscript{19} Six pounds of copper sulphate, four pounds of lime and 50 gallons of water.
On Series III less lime was used in this spraying than in former ones, the formula this time being one pound paris green, one pound lime, fifty gallons water. The other three series were treated as in the first spraying. All applications in this spraying were at the rate of 225 gallons per acre. Following this spraying rain fell on August 13, 16, 17, 19 and 20.

*Fifth spraying.*—The fifth and last spraying was made August 25. There were no flea-beetles and no Colorado potato beetles. The rows of Series II and III were now so much affected by blight that it would be difficult to detect paris green injury should any occur. Consequently, there was no object in using paris green and so it was omitted in this spraying. In spite of the frequent rains since the fourth spraying the rows of Series IV and V were still so thoroughly covered with bordeaux that they scarcely needed spraying. However, it was done with the bordeaux prepared as in the first spraying, the rate of application being 200 gallons per acre.

*Chemical analysis of the paris green.*—Paris green is variable in chemical composition. The greater the percentage of soluble arsenic contained in it the greater the liability of its injuring foliage.** Hence, it is important to know the chemical composition of the paris green used in this experiment. It was purchased of a Geneva merchant for 16 cents per pound. Analyses made by Mr. W. H. Andrews gave the following results:

<table>
<thead>
<tr>
<th>Total arsenious oxide</th>
<th>59.85 per ct.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot; copper oxide</td>
<td>27.63 &quot;</td>
</tr>
</tbody>
</table>

Soluble arsenic oxide obtained by treating one gram with one liter of water:

<table>
<thead>
<tr>
<th>Treated 24 hours</th>
<th>Treated 10 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st analysis</td>
<td>1.83 per ct.</td>
</tr>
<tr>
<td>2d &quot;</td>
<td>2.08 &quot;</td>
</tr>
<tr>
<td>3d &quot;</td>
<td>1.76 &quot;</td>
</tr>
<tr>
<td>1st analysis</td>
<td>6.81 per ct.</td>
</tr>
<tr>
<td>2d &quot;</td>
<td>6.81 &quot;</td>
</tr>
</tbody>
</table>

**J. K. Haywood has reported (U. S. Dept. Agr. Bureau of Chemistry Bul. 82) the results of some paris green spraying experiments which "were undertaken to show how much soluble arsenious oxide may be present in samples of paris green used for spraying purposes without injury to the foliage" of certain fruits. So far as known to the writers no such work has been done for the potato plant.
RESULTS.

Effect on the foliage.—Throughout the entire experiment there were no indications that the paris green caused any injury to the foliage whatever. While looking for such injury on July 9, it was observed that occasionally a leaf was affected with a trouble diagnosed as sun scald. On the tips and margins of some of the leaflets of the younger leaves there were dead, copper-colored areas one-half inch to one inch across. They were not sufficiently numerous to attract the attention of a casual observer. It is believed that they were caused by the action of the sun (on July 8) on tender, rapidly growing foliage. Certainly, the paris green had nothing to do with them, for they were quite as numerous on the check rows as on the rows treated with paris green.

The only other dead spots on the leaves were those caused by late blight, Phytophthora infestans, and these could be easily and positively identified by the presence of the fungus. There were no spots of early blight or anything resembling it.

Effect on late blight.—An unexpected result of the experiment was the discovery that paris green is of considerable value as a preventive of late blight, Phytophthora infestans. Traces of this disease were first seen on the check rows (Series I) July 23. By August 2 the rows of Series I, II and III were plainly showing blight and there was evidently more of it on the check rows than on the adjacent rows treated with paris green in water or on those treated with paris green in lime water. Series IV and V, sprayed with bordeaux, were not affected.

On August 10 the check rows were seriously affected and the superiority of the rows treated with paris green was pronounced.

On September 8 the check rows were nearly dead from blight, while the rows receiving paris green (Series II and III) still retained about one-half their foliage and the rows receiving bordeaux (Series IV and V) were in almost full foliage. It was very plain that the application of paris green had materially checked the blight but that the bordeaux had been much more effective. The rows treated with paris green in water and those treated with paris green in lime water were equally blighted and there was no apparent difference between the rows treated with bordeaux and paris green and those treated with bordeaux alone.
On September 16, Rows 14, 15, 16, 17 and 18 were photographed (See Plate I). Row 14 (bordeaux and paris green) and Row 15 (bordeaux only) were about equal. Two-thirds of their foliage was still green. On Row 16 (check) the plants were all dead and dry over at least one-half the length of the row. Row 17 (paris green in water) and Row 18 (paris green in lime water) were about equal. Both were superior to the check, but markedly inferior to the bordeaux rows Nos. 14 and 15. Most of the plants were still alive with tufts of green leaves at their tips.

Effect on the yield.—The potatoes were dug by hand on October 17 and 18. The product of each row was carefully sorted into two sizes, marketable and unmarketable, and the weight of each size taken. All tubers showing the least sign of rot were rejected. On all of the rows there was an occasional rotten tuber, but they were so few that no record of their weight was kept. Moreover, on Series I, II and III most of the affected tubers were so far advanced in decay that it would have been impossible to determine their weight accurately. The yields are shown in the accompanying table:

12 In order to bring out better the condition of the foliage on the different rows a white background was made by sifting air-slaked lime over the ground under the plants.

13 Row 16 fell in a dead-furrow and for that reason its yield was left out of consideration in making up the yields of the different series. However this had no bearing on the blighting of the tops. Plants are neither more nor less subject to late blight for being in a dead-furrow.
### Table I.—Showing Yields in the Paris Green Experiment.

<table>
<thead>
<tr>
<th>Section</th>
<th>Row</th>
<th>Treatment</th>
<th>Yield per row(^{14})</th>
<th>Yield per acre.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Marketable</td>
<td>Small</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>Check. Not sprayed</td>
<td>215</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Paris green in water</td>
<td>263 ½</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>&quot; &quot; &quot; lime water</td>
<td>249</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>&quot; &quot; &quot; bordeaux</td>
<td>385 ½</td>
<td>22 ½</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Bordeaux only</td>
<td>369 ½</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>Check. Not sprayed</td>
<td>220</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Paris green in water</td>
<td>272</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>8(^{15})</td>
<td>&quot; &quot; &quot; lime water</td>
<td>249 ½</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>9(^{15})</td>
<td>&quot; &quot; &quot; bordeaux</td>
<td>375 ½</td>
<td>21 ½</td>
</tr>
<tr>
<td></td>
<td>10(^{15})</td>
<td>Bordeaux only</td>
<td>400</td>
<td>21</td>
</tr>
<tr>
<td>C</td>
<td>11(^{15})</td>
<td>Check. Not sprayed</td>
<td>297</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Paris green in water</td>
<td>279</td>
<td>27 ½</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>&quot; &quot; &quot; lime water</td>
<td>277 ½</td>
<td>31 ½</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>&quot; &quot; &quot; bordeaux</td>
<td>417</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Bordeaux only</td>
<td>380 ½</td>
<td>18</td>
</tr>
<tr>
<td>D</td>
<td>16(^{16})</td>
<td>Check. Not sprayed</td>
<td>155 ½</td>
<td>37 ½</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Paris green in water</td>
<td>271</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>&quot; &quot; &quot; lime water</td>
<td>258</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>&quot; &quot; &quot; bordeaux</td>
<td>402 ½</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Bordeaux only</td>
<td>408 ½</td>
<td>26</td>
</tr>
<tr>
<td>E</td>
<td>21</td>
<td>Check. Not sprayed</td>
<td>195</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>Paris green in water</td>
<td>255</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>&quot; &quot; &quot; lime water</td>
<td>245</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>&quot; &quot; &quot; bordeaux</td>
<td>382</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Bordeaux only</td>
<td>365</td>
<td>19 ½</td>
</tr>
</tbody>
</table>

\(^{14}\) Length of rows, 290.4 feet.

\(^{15}\) In the second spraying these rows were wrongly sprayed as follows:
- Row 11. Bordeaux only.

\(^{16}\) In a dead-furrow.

As was to be expected from the condition of the foliage, the rows treated with paris green in water (Series II) and those treated with paris green in lime water (Series III) gave considerably larger yields than the check rows, while the rows receiving bordeaux mixture (Series IV and V) far outyielded all the others. Owing to an error made on Rows 8, 9, 10 and 11 in the second
spraying the yields of these rows must be left out of consideration. The very low yield of Row 16 is due to its being in a dead-furrow, and so this row, also, should be rejected.

Although there was no error of any kind in connection with Rows 12, 13, 14 and 15 it is not entirely fair to use them in making up the average yields of the different series because the rejection of Row 16 leaves them without a proper check. Accordingly, Rows 8 to 16 inclusive have been omitted in preparing the following table:

**Table II.—Yield by Series in the Paris Green Experiment.**

<table>
<thead>
<tr>
<th>Series</th>
<th>Rows.</th>
<th>Treatment.</th>
<th>Yield of marketable tubers per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1, 6 and 21.</td>
<td>Check; not sprayed; bugs hand picked.</td>
<td>175 lbs.</td>
</tr>
<tr>
<td>II</td>
<td>2, 7, 17 and 22.</td>
<td>Paris green in water, four times.</td>
<td>221 9</td>
</tr>
<tr>
<td>III</td>
<td>3, 18 and 23.</td>
<td>Paris green in lime water, four times.</td>
<td>208 53</td>
</tr>
<tr>
<td>IV</td>
<td>4, 19 and 24.</td>
<td>Paris green in bordeaux four times and bordeaux alone once.</td>
<td>325 —</td>
</tr>
<tr>
<td>V</td>
<td>5, 20 and 25.</td>
<td>Bordeaux alone, five times; bugs hand picked.</td>
<td>317 30</td>
</tr>
</tbody>
</table>

Paris green in water increased the yield 46 bu. 9 lbs. per acre.

" " lime water increased the yield 33 bu. 53 lbs. per acre.

" " with bordeaux increased the yield 150 bu. per acre.

Bordeaux alone increased the yield 142 bu. 30 lbs. per acre.

**Discussion of results.**—The results of this experiment do not support the belief that Paris green is injurious to the potato plant. On the contrary, it appears that Paris green, properly applied, may be decidedly beneficial in preventing the ravages of late blight. At no time in the course of the experiment was there any indication that Paris green had injured the foliage. From August 2 until the end of the season the rows receiving Paris green were conspicuously more perfect in foliage than were the rows without Paris green. Likewise, the yield was in favor of the rows receiving Paris green. The rows treated with Paris green in bordeaux (Series IV) yielded slightly more on the average than the rows treated with bordeaux only (Series V), al-
though the bordeaux in both cases was exactly the same. The only difference in the treatment of the two series was the use of paris green in the first four sprayings on Series IV. It is not certain that the paris green was responsible for the increased yield on Series IV, but in view of the fact that paris green has considerable fungicidal value it is not an unreasonable conclusion that such was the case. At least, the paris green did no harm.

It is worthy of note that in every section the row treated with paris green alone outyielded the adjacent row treated with paris green in lime water, the average difference being at the rate of 12 bu. 16 lbs. per acre. This difference is so small that it is not safe to base a conclusion upon it, but it suggests that the lime may have been detrimental. Of course there is no reason to believe that the lime injured the foliage. As a matter of fact there was no evidence of any injury, but it is possible that the lime counteracted the fungicidal action of the paris green. As there was no tendency to paris green injury in the experiment no benefit from the lime could be expected. Had the conditions been such as to induce paris green injury the results of the experiment would undoubtedly have been in favor of the lime. We would not discourage the use of lime with paris green when the choice lies between using the paris green alone and using it in lime water. However, we believe that the best method of all is to use the paris green always with bordeaux mixture.

That paris green possesses some value as a fungicide is not a new idea. As early as 1891 Goff at the Wisconsin Station showed that apple scab may be materially checked by spraying with paris green in lime water. In experiments made by Lodeman in 1892 paris green used alone reduced the injury from scab on King apples 17.7 per ct. and on Baldwins 7 per ct. The use of paris green and land plaster as a preventive of potato blight was suggested as early as 1886. However, little or no attention

19 B. F. J. in Country Gentleman for May 27, 1886, p. 405; see also Lodeman, Spraying of Plants, p. 98.
Plate II—View in the Arsenite of Lime Experiment.

Row 5, Check; 6, Arsenite of Soda in Lime Water; 7, Arsenite of Soda in Bordeaux; 8, Bordeaux Alone.
Photographed September 16.
was given the matter. The superior merits of bordeaux mixture as a fungicide have so overshadowed those of paris green that the fungicidal properties of the latter have been lost sight of completely. Time and again the statement has been made that paris green is not a fungicide. As recently as 1903, Jones and Morse in discussing the results of a potato spraying experiment at the Vermont Station concluded that, "Neither paris green nor bug death used alone have any value in checking late blight."

In the experiment here at Geneva the results were so striking that there can be no doubt that paris green materially checked the potato blight and thereby increased the yield at the rate of 46 bushels per acre. However, it should be noted that late blight was exceedingly virulent at Geneva in 1904 and that the quantity of paris green used (about 12 lbs. per acre) was larger than farmers usually apply. It should be noted, also, that under parallel conditions 5 sprayings with bordeaux mixture increased the yield 142½ bushels per acre. Thus it appears that paris green has at least one-third the fungicidal value of bordeaux mixture.

Jones has called attention to the fact that paris green injury is especially liable to occur where the epidermis of the potato leaf has been broken, as for example, around the punctures made by flea-beetles. In this experiment there were no flea-beetles, but Colorado potato beetles mutilated the leaves on some of the plants without any paris green injury resulting there from.

The failure of paris green to produce injury in this experiment cannot be attributed to unfavorable weather conditions. Throughout the season there was an abundance of rain which is generally regarded as favorable to paris green injury.

As previously stated, the chemical composition of paris green is variable. Some samples contain a larger percentage of soluble arsenic compounds than others and consequently some are more liable to injure foliage than are others. In some states this is regulated by law. In New York legal paris green must not contain more than 3½ per ct. of soluble arsenic compounds. Analyses made at this Station show that the great majority of the paris

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green offered for sale in New York complies with the law. As regards the content of soluble arsenic the paris green used in this experiment is fairly representative of the paris green found on the market.

The conclusion is that paris green is not injurious to potato foliage when properly applied; that is, in moderate amount (one to two pounds per acre) with lime water or bordeaux mixture evenly distributed over the foliage.

THE EXPERIMENT WITH ARSENITE OF LIME.

PLAN AND METHODS.

This experiment included 20 rows 290.4 feet long and three feet apart, each row having an area of one-fiftieth acre. The potatoes were of the variety Rural New Yorker No. 2. They were planted May 28, 15 inches apart in the row. Each row received ten pounds of commercial fertilizer applied by hand as uniformly as possible in the furrows before planting. For some reason not well understood Rows 13 to 20 inclusive did not come up as well as they should. However, there was a fair stand of plants.

The 20 rows were divided into four series of five rows each as follows:

        II. "  2, 6, 10, 14, 18.  Sprayed 4 times, arsenite of soda in lime water.
        IV. "  4, 8, 12, 16, 20.  Sprayed 5 times with bordeaux alone. Bugs hand picked.

The rows of Series I received no insecticide or fungicide of any kind. Bugs were removed by hand picking as in the experiment with paris green.

The stock solution of arsenite of soda was prepared by the Kedzie formula given on page 268. In different sprayings the quantity used varied from 2 to 4 pints in 50 gallons. When used with lime water (Series II) two pounds of quicklime was added for each pint of the arsenite-of-soda solution. As in the paris green

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See Bulletins 204 and 222 of this Station.
experiment, the spraying was done thoroughly and uniformly with a knapsack sprayer.

FIRST SPRAYING.

The first spraying was made on July 7 and 8 when the plants were 6 to 8 inches high.\textsuperscript{33} The rows of Series II were sprayed with the following mixture: — 4 pints stock solution of arsenite of soda, 8 lbs. quicklime and 50 gallons water. The lime was slaked slowly as for whitewash and afterward diluted to 50 gallons. The arsenite-of-soda stock solution was then added and after thorough stirring spraying was begun at once.

On Series III the following mixture was used: 6 lbs. copper sulphate, 4½ lbs. quicklime, 3 pints of the arsenite-of-soda stock solution and 50 gallons of water.\textsuperscript{34} The copper sulphate, lime and water were first made into bordeaux mixture, the arsenite of soda then added and spraying begun at once.

On Series IV bordeaux alone was used.

In all cases the spray mixtures were applied at the rate of 100 gallons per acre.

On July 12, 1.92 inches of rain fell. The following day it was observed that the rows of Series II, sprayed with arsenite of soda in lime water, were showing spray injury. The extent of the injury was not great enough to materially affect the crop, but there was positive injury. Leaves here and there were showing dead brown areas of various shapes and sizes. Some of the spots were on the margins of the leaves and others on the interior. Certain weeds, also, were injured; namely, rough pigweed (*Amaranthus retroflexus*), yellow foxtail (*Echinochloa crus-galli*) and Polygonum sp. Lamb's quarters (*Chenopodium album*) was wholly uninjured.

On the rows of Series III, where the arsenite of soda had been applied with bordeaux there was no evidence of spray injury. The check rows, also, were perfect in foliage except for traces of sunscald as in the paris green experiment (See page 272).

\textsuperscript{33} Series IV on July 7, the other three series on July 8.

\textsuperscript{34} This formula was used by mistake. It was intended to use 6 lbs. copper sulphate, 8 lbs. lime and 4 pints arsenite of soda in order to make this series strictly comparable with Series II.
SECOND SPRAYING.

This spraying was made July 23 and 25. Series II was sprayed with 3 pints of arsenite of soda and 6 lbs. of lime in 50 gallons of water. Series III, received bordeaux mixture (6–6–50 formula) with 3 pints of arsenite of soda to 50 gallons added just before spraying was begun. Series IV received only bordeaux of the 6–6–50 formula.

25 The rows of Series IV and Rows 3, 7 and 11 of Series III, were sprayed on the afternoon of July 23. It then commenced to rain and there was no opportunity to finish the spraying until July 25.
In this spraying all spray mixtures were applied at the rate of 150 gallons per acre.

At 4 P. M. July 26 the rows of Series II, sprayed the day before were found to be considerably injured as in the previous spraying. Leaves of all ages were affected with large copper-colored dead spots some of which closely resembled the spots of late blight (See Fig. 1). The rows of Series III were not in the least injured.

THIRD SPRAYING.

The third spraying was made August 1. The quantity of arsenite of soda was again reduced. Series II was sprayed with 2 pints of arsenite of soda and 4 lbs. of lime in 50 gallons of water, while Series III received the same amount of arsenite of soda in bordeaux made by the 6-4-50 formula. Series IV received only bordeaux of the same formula.

The rate of application was 200 gallons per acre.

But little if any injury resulted from this spraying.

FOURTH SPRAYING.

The fourth spraying was done August 12 as follows:

Series I. Check. Not sprayed.

II. 2 pints arsenite of soda + 4 lbs. lime + 50 gallons water.

III. 2 "  "  "  "  " +50 gal. bordeaux (6-4-50 formula).

IV. Bordeaux only (6-4-50 formula).

The rate of application was 225 gallons per acre.

On August 20 it was observed that Series II had been severely injured by the spraying, but Series III showed no trace of injury.

FIFTH SPRAYING.

The fifth and last spraying was made August 30 on Series III and IV with bordeaux only. Series II was so nearly dead from blight and spray injury that there was no object in further treatment. Probably only about one-fifth of the foliage on Series II was alive on this date. The check rows still retained about one-fourth their foliage the remainder having been killed by blight.

On September 16, Rows 5, 6, 7 and 8 were photographed. (See Plate II.) Row 5 (check) and Row 6 (arsenite of soda in lime water) were entirely dead and the stems dry. Row 7 (arsenite of soda in bordeaux) and Row 8 (bordeaux only) were equal.

There was a shower at 2 P. M.
in appearance. About three-fourths of the foliage on these rows was still green.

**YIELDS.**

The potatoes were dug by hand on October 22. The method of sorting and the loss from rot were the same as in the paris green experiment. (See page 273.) The yields are shown in tables III and IV.

**Table III.—Yields in the Arsenite of Lime Experiment.**

<table>
<thead>
<tr>
<th>Section</th>
<th>Row</th>
<th>Treatment</th>
<th>Yield per row.</th>
<th>Yield per acre.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Marketable</td>
<td>Small</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>Check</td>
<td>188</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Arsenite + lime water</td>
<td>118</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Arsenite + bordeaux</td>
<td>411 1/2</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Bordeaux only</td>
<td>379</td>
<td>17</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>Check</td>
<td>162 1/2</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Arsenite + lime water</td>
<td>100</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Arsenite + bordeaux</td>
<td>411</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Bordeaux only</td>
<td>414</td>
<td>24</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
<td>Check</td>
<td>188</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Arsenite + lime water</td>
<td>111</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Arsenite + bordeaux</td>
<td>389</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Bordeaux only</td>
<td>402 1/2</td>
<td>15</td>
</tr>
<tr>
<td>D</td>
<td>13</td>
<td>Check</td>
<td>181</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Arsenite + lime water</td>
<td>126 1/2</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Arsenite + bordeaux</td>
<td>241</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Bordeaux only</td>
<td>345</td>
<td>9</td>
</tr>
<tr>
<td>E</td>
<td>17</td>
<td>Check</td>
<td>135</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Arsenite + lime water</td>
<td>113</td>
<td>25 1/2</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>Arsenite + bordeaux</td>
<td>322</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Bordeaux only</td>
<td>438</td>
<td>8 1/2</td>
</tr>
</tbody>
</table>

Arsenate of soda stock solution.

**Discussion of the Results.**

From the results of this experiment it appears that the use of arsenite of soda in lime water on potato foliage is attended with considerable risk. Injury to the foliage resulted from the use of 8 pints of arsenite of soda per acre in the first spraying and 9 pints per acre in the second and fourth sprayings. Based on the arsenic it contains, nine pints of the arsenite-of-soda stock solution are equivalent in poisoning properties to 36 ounces of paris green
TABLE IV.—YIELD BY SERIES IN THE ARSENITE OF LIME EXPERIMENT.

<table>
<thead>
<tr>
<th>Series</th>
<th>Rows.</th>
<th>Treatment.</th>
<th>Yield of marketable tubers per acre.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1, 5, 9, 13 and 17</td>
<td>Check; not sprayed; bugs hand picked.</td>
<td>Bu.  Lbs.</td>
</tr>
<tr>
<td>II</td>
<td>2, 6, 10, 14 and 18</td>
<td>Sprayed 4 times, arsenite of soda in lime water.</td>
<td>94  45</td>
</tr>
<tr>
<td>III</td>
<td>3, 7, 11, 15 and 19</td>
<td>Sprayed 4 times with arsenite of soda in bordeaux and once with bordeaux alone.</td>
<td>295 45</td>
</tr>
<tr>
<td>IV</td>
<td>4, 8, 12, 16 and 20</td>
<td>Sprayed 5 times with bordeaux alone; bugs hand picked.</td>
<td>329 45</td>
</tr>
</tbody>
</table>

Arsenite of soda in lime water reduced the yield 47 1/2 bu. per acre.
Arsenite of soda with bordeaux increased " " 133 1/2 " " " "
Bordeaux alone increased the yield 187 1/2 bu. per acre.

which is not an excessively large quantity to apply per acre.
In the paris green experiment twice this amount of paris green per acre was used without the least injury to the foliage. (See pages 269, 275.)

Why injury resulted from the fourth treatment with arsenite of soda in lime water and not from the third is not clear. The spray mixture was prepared and applied in identically the same manner in both cases, except that a slightly greater quantity was used in the fourth spraying. The difference in rainfall may have had something to do with it. The third spraying was made August 1. On the night of the same day .52 inch of rain fell; on August 2, .02 inch and on August 5, .07 inch. After this there was no more rain until August 13. The fourth spraying was made August 12, following which date the rainfall was as follows: August 13, .18 inch; 16, .16 inch; 17, .31 inch; 19, .76 inch. The injury was not observed until August 20, but it is possible that it occurred earlier.

An interesting result of the experiment was the discovery of the part which copper sulphate plays, in connection with the lime, in preventing the caustic effect of the arsenite of soda. When arsenite of soda was applied with lime water injury to the foliage resulted; but when the same quantity of arsenite was applied with bordeaux mixture there was no injury. This happened three times. In the fourth spraying the quantities of
arsenite, lime and water were the same in both cases the only difference being that one mixture contained copper sulphate while the other did not. The conclusion is plain that the copper sulphate was, in some way, responsible for the absence of spray injury on the rows to which it was applied. It appears that the caustic effect of the arsenite of soda is prevented more effectively by copper sulphate and lime acting together than by either one alone. In fact there is no evidence that copper sulphate alone is of any value whatever for this purpose. On the contrary it has been shown by Gillette \(^{28}\) and also by Kilgore \(^{29}\) that arsenites are more injurious to foliage when applied in copper sulphate solution than when applied in water.

Heretofore, it has been supposed that bordeaux mixture prevents the caustic action of arsenites simply by virtue of the lime it contains. \(^{30}\) The results of this experiment show that not only the lime but the copper sulphate, also, is a factor in preventing injury. It is also shown that a great excess of lime in the bordeaux is unnecessary. Two pints of the arsenite of soda solution may be used safely with 50 gallons of bordeaux made by the regular 6–4–50 formula without the addition of extra lime.

The fact that Series III treated with arsenite of soda in bordeaux mixture yielded at the rate of 34 bushels per acre less than Series IV treated with bordeaux mixture alone tends to show that the addition of the arsenite was deleterious; but judgment on this point should be deferred until further tests have been made. The yields in this experiment are not entirely reliable. The potatoes came up somewhat unevenly and some of the plants were considerably injured by Colorado potato beetles. As there was at no time any indication of arsenical injury to the foliage on Series III it is difficult to understand how the arsenite could have affected the yield.

It is advised that the arsenite of soda be used on potatoes only in combination with bordeaux mixture.


\(^{30}\) Fraser's statement (The Potato, p. 138) that, "The copper sulphate in the bordeaux mixture seems to prevent the caustic action" (of arsenite of soda), and Stewart's article on this subject (Proc. W. N. Y. Hort. Soc. 50: 87) are both based on the experiment described in this bulletin.