THE EFFECT OF WOOD ASHES AND ACID PHOSPHATE ON THE YIELD AND COLOR OF APPLES.

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*Riverhead, N. Y.
THE EFFECT OF WOOD ASHES AND ACID PHOSPHATE ON THE YIELD AND COLOR OF APPLES.

U. P. HEDRICK.

SUMMARY.

1. Because of the condition of growth of the plant, manner of development of the product, and nature of both plant and product, the apple is difficult to deal with experimentally in the matter of fertilization.

2. The apple growers in New York should give attention to the fertility of their soils; for the orchards are growing old; the soil of some orchards was not originally fertile; and double-cropping has exhausted the fertility of many orchards.

3. This experiment has to do with potash, phosphoric acid and lime as found in wood ashes and acid phosphate. It was begun in 1893 and completed in 1904.

4. The seat of the experiment is a 55-year-old orchard on the Station grounds. The location is a sloping upland with a medium heavy clay soil. The orchard had been in grass for several years before the experiment.

5. Throughout the experiment the orchard was given clean cultivation until about August 1 and was then seeded to a cover crop of oats, barley or clover.

6. The trees were 43 years old when the experiment was started. There were 94 trees in the test representing the following varieties: Baldwin, Fall Pippin, Rhode Island Greening, Roxbury and Northern Spy. The orchard was divided into eight plats, four treated and four untreated.

7. Wood ashes were applied to the treated plats at the rate of 100 pounds per tree or 4,800 pounds per acre. During the
last seven years of the experiment acid phosphate was applied at the rate of 8½ pounds per tree or 408 pounds per acre. Calculations made from analyses of the fertilizers show that, on the average, 169 pounds per acre of actual potash were applied each year; 72 pounds of phosphoric acid from the ashes and 57 pounds from the acid phosphate; and lime at the rate of 32 pounds per tree, 1,536 pounds per acre. The amounts are in excess of the usual recommendations of these fertilizers for apples.

8. The effects of the fertilizer were measured by two standards, yield of fruit and color of fruit.

9. The annual average increases per tree on the treated plats for the several varieties were, in bushels, as follows: Fall Pippin, 1.05; Roxbury, 2.65; Rhode Island Greening, —0.34; Northern Spy, 2.55; Baldwin, 0.28.

10. From a financial standpoint the results are practically negative. The estimated increase in value of the crop on the treated plats for a hypothetical five acres is $99.00. The estimated value of the fertilizers for the above area is $74.50, leaving a gain of but $24.50, which does not more than pay for handling the fertilizers.

11. An interesting fact is that both treated and untreated plats increased markedly in yield from 1893 to 1904. The probable explanation is, that prior to 1893 the orchard was in sod, but during the experiment was kept under cultivation and grew more productive under the treatment.

12. The results as to color of fruit lack uniformity and were not decided enough in a sufficient number of the twelve seasons to enable us to state that the fertilizers applied improved the color of the apples. The influence on color was most marked in the seasons when the climatic conditions were unfavorable to the development of the fruit.

13. This experiment shows that 57 years of orchard cropping has not reduced the soil of the Station orchard to the condition where it needs a “complete” fertilizer. The fact that plowing under leguminous crops gives beneficial effects
in the orchard shows that the soil is having a one-sided wear. It needs nitrogen and humus rather than potash and phosphoric acid.

14. The results of this experiment should not lead the fruit grower to conclude that his soil does not need the nutrients supplied. They suggest, however, since the soil of the Station orchard is an average piece of soil for western New York, that there may be many other orchards in the State that do not need these fertilizers.

15. The fertilizers applied may not have been thrown away. Phosphoric acid, potash and lime will remain in the soil for a time at least.

16. The practical application of the results obtained by this experiment is that fruit growers should not apply manures in quantity until good evidence has been obtained as to what food elements, if any, are wanted in the soil.

17. As long as trees are making good wood growth and producing average crops of well colored fruits, it may be taken as granted that they need no additional food from fertilizers. If the contrary be true the fruit grower should put in operation tests with fertilizers to ascertain what plant foods his soil needs.
THE PROBLEM OF ORCHARD FERTILIZATION.

Feeding the apple tree is a complex problem. There is a series of phenomena in the growth of all orchard trees very difficult to deal with in fertilization. Among these are: The perennial nature of the plants; the several seasons of growth before a crop is borne; the continuous cropping without chance for rotation; the facts that tree growth must proceed with fruit development, and that a whole season is required for the development of the fruit; the uneven production in different varieties and on different trees; and the necessity of the storage of plant food in bud and branch. These form a set of conditions so different from those encountered in growing general farm crops that the practices in fertilizing cereals and herbaceous plants do not apply to orchard trees.

Because of the nature of the plant and of its products, as set forth above, it is exceedingly difficult to measure the value of fertilizers in an apple orchard, and this complicates the problem of their use still more. Thus, who can give the relative values, as measures of the worth of manurial treatment, of size of tree, number and area of leaves, the fruit and its qualities, and such abstract characters as hardiness, productiveness, longevity and early bearing? Again, the effects of added or modified plant food cannot be seen in an orchard in one season, as with farm crops, but several seasons are required to guage their influence with satisfactory accuracy.

The apple growers of New York should be especially interested in maintaining and increasing the fertility of their soils. The orchards are growing old; many, if not most of them, are past their prime and the trees are beginning to show the decay of old age. However trees and herbaceous plants may differ in use of food, they agree in this;—each succeeding crop harvested from either finds the soils somewhat poorer. Again,
much of the soil upon which apples have been planted did not originally possess high fertility; and such orchards are now in need of plant food. Then, too, some orchards have been double-cropped until the plant food in the soil is exhausted. Quite as detrimental to the soil as double-cropping is the lack of tillage. Jethro Tull announced in 1733 that "tillage is a means of increasing the pasture of a plant," and since that time we have come to know that it is the chief of all means of maintaining soil fertility. Orchards can be grown profitably without tillage only in the most fertile soils; unfortunately, however, the operation is neglected in many New York orchards, the soils of which are not fertile.

It is scarcely necessary to point out that fruit-growers have little definite knowledge of the manurial requirements of any of the tree fruits. In fact, it is only within the past few years that there has been any thought that orchards needed fertilizers, the assumption having been that trees could take care of themselves in this, as well as in many other respects. The literature of the subject is scant, fragmentary, and for most part unreliable. There are records of but very few long-continued experiments with fertilizers for the apple. The apple grower cannot carry on fertilizer experiments of much value to others than himself and it is a difficult task for the experiment station.

The investigation discussed in the following pages throws light only on the use of potash and phosphoric acid as found in certain fertilizers and as they affect but two qualities of the apple—yield and color of fruit; but the experiment has been carried on with care and exactness for twelve years, and since these are two of the chief mineral constituents of the food of the apple, and the fertilizers in which they were used are common ones, and the tree qualities important ones, the work, though not comprehensive, should be valuable, and especially so, in view of the meagerness of our knowledge as to the effects of these foods on the apple.
THE EXPERIMENT.

The trial of wood ashes as a fertilizer for apples was begun by Professor S. A. Beach in the Station orchard in 1893 and was carried on by him to its completion at the close of the season of 1904; a preliminary report of the experiment was published in Bulletin No. 140 from this Station in 1897. The remaining data were turned over to the writer, as Professor Beach's successor, and this report is based on the one published in Bulletin No. 140 and on the subsequent data. The experiment was planned to determine the effects of wood ashes on the scab fungus of the apple as well as the value of the ashes as a fertilizer, but when it was found, after liberal applications of the ashes for five years, that the immunity of the apples to the fungus was in no degree increased, this phase of the experiment was dropped.

Beginning with the season of 1898 the test of wood ashes was supplemented by one with acid phosphate, and the two experiments were carried on jointly until the close of the season of 1904. Since wood ashes contain considerable quantities of phosphoric acid and lime, the original experiment was really one with potash, phosphoric acid and lime as found in wood ashes.

Location and character of soil.—The seat of the experiment is a mature apple orchard, 55 years old at the close of the experiment, on the Station grounds. The location is a piece of upland sloping to the south and running into the bottom land of a small creek. The soil is a heavy clay loam from twelve to eighteen inches deep, resting on a still heavier, compact clay sub-soil; this in turn is superimposed on shale to be found at a depth of from four to six feet near the creek, to from fifteen to twenty in parts of the orchard. An analysis of essentially the same soil taken in an adjoining field shows the following constituents:
### Table I.—Composition of Soil of Station Orchard.*

<table>
<thead>
<tr>
<th></th>
<th>Top-soil.</th>
<th>Sub-soil.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>1.23</td>
<td>1.04</td>
</tr>
<tr>
<td>Organic matter</td>
<td>4.09</td>
<td>2.78</td>
</tr>
<tr>
<td>Insoluble</td>
<td>81.83</td>
<td>80.09</td>
</tr>
<tr>
<td>Soluble silica</td>
<td>.30</td>
<td>.23</td>
</tr>
<tr>
<td>Iron and alumina</td>
<td>9.34</td>
<td>10.95</td>
</tr>
<tr>
<td>Lime</td>
<td>.62</td>
<td>.96</td>
</tr>
<tr>
<td>Magnesia</td>
<td>.85</td>
<td>1.26</td>
</tr>
<tr>
<td>Soda</td>
<td>.33</td>
<td>.36</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Potash</td>
<td>.89</td>
<td>1.23</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>.093</td>
<td>.097</td>
</tr>
<tr>
<td>Ammonia</td>
<td>.255</td>
<td>.181</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>.210</td>
<td>.149</td>
</tr>
<tr>
<td>Chlorine, carbonic acid, undetermined, etc.</td>
<td>.43</td>
<td>.13</td>
</tr>
</tbody>
</table>


These analyses show that the sub-soil differs from the top-soil in having "less insoluble matter, more iron and alumina, lime, potash and soda, less organic matter by twenty-five per ct., less phosphoric acid, and thirty per ct. less nitrogen." Both top and sub-soil, it can be seen, have a large percentage of potash and of lime.

The soil is not an ideal one for apples, probably not better than the average western New York clay soil for this fruit. The trees make a good growth and fruit sets in abundance, but with most varieties, all in this experiment, the size of the product is small; the fruit does not take on high color; and in many seasons does not properly mature. Though well drained, the soil is yet wet and heavy, probably because of the fine state of division of the soil particles. The tillage given the orchard and the cover crops planted in it have greatly improved the character of the soil, though rain quickly renders it unworkable. The root-run, because of the quality and depth of the soil, is too limited for the best results in growing apples.
An inspection shows that there are no considerable variations of soil in the orchard, the chief one being a tendency, as the ground approaches the bottom land of the creek, to less depth in top-soil and to a coarser texture. The difference is not so great, however, that the value of the field for experimental purposes is impaired to any great degree. In general, the soil is such that the trees behave essentially as in the great majority of the orchards in the region in which the Station is located.

Before the experiment was begun, in 1893, the orchard had been in grass for several years. During the winter of 1892-3, it was given a liberal application of barnyard manure, which was plowed under the following spring. Throughout the experiment the orchard has been given clean cultivation until about August 1st, and then seeded to a cover crop of oats, barley or clover.

The trees.—The experimental plats contain 241 bearing trees, 124 of which are in full bearing. Of these, however, there are a few varieties which are not well enough represented in treated and untreated plats to permit them to be used in the experiment. Excluding these odd varieties there remain 94 trees, 47 in each division of the experiment. The varieties represented are: Baldwin, Fall Pippin, Rhode Island Greening, Roxbury and Northern Spy. The numbers of treated and untreated trees of each of these varieties are:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Treated</th>
<th>Untreated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baldwin</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Fall Pippin</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Rhode Island Greening</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Roxbury</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Northern Spy</td>
<td>15</td>
<td>13</td>
</tr>
</tbody>
</table>
The orchard was divided into eight plats, numbered from 1 to 8. The accompanying diagram of the orchard, page 221, shows the positions of the plats and of the trees in each. The shaded portions of the diagram indicate the plats which were treated with ashes. The trees in the experiment are indicated by number in the explanation, and by shading in the diagram.

The trees selected were planted in 1850 and were, therefore, 43 years old when the experiment was begun. The orchard as a whole does not form a uniform block, but the trees selected, as numbered above, were fairly uniform and in the main were well adapted for the investigation.

THE FERTILIZERS.

Wood ashes were applied to the four treated plats at the rate of 100 pounds per tree annually, with the exception of two years, 1901 and 1902, when the applications were omitted. As there are 48 trees per acre, 4,800 pounds were applied per acre. The ashes were thoroughly mixed, weighed separately for each tree, and applied broadcast to a line midway between adjacent rows. Applications were made in the spring and were well worked into the ground. No other fertilizer was applied to any part of the orchard during the first five years of the experiment; cover crops were plowed under as follows:—

1893—Oats and peas 1899—Crimson clover
1894—Crop not stated 1900—Rye
1895—Crop not stated 1901—Oats
1896—Sweet clover 1902—Barley
1897—Mammoth clover 1903—Crimson clover
1898—Crimson clover 1904—Mammoth clover

Acid phosphate was added to the treated plats during the last seven years of the experiment in quantities stated hereafter.

Analyses were made of each application to determine the percentage of potash and with the following results:—
EXPLANATION OF DIAGRAM.

Baldwin, treated, Nos. 10, 101, 102, 108, 109, 125, 126, 127, 128.
Baldwin, untreated, Nos. 81, 111, 133, 136, 137, 207.
Fall Pippin, treated, Nos. 31, 33, 34, 35, 37, 38, 39.
Fall Pippin, untreated, Nos. 1, 4, 5, 6, 8, 9.
R. I. Greening, treated, Nos. 50, 51, 52, 54, 55, 56, 58, 70, 105, 107, 129, 146.
Roxbury, treated, Nos. 143, 145, 147, 149.
Roxbury, untreated, Nos. 150, 153, 161, 175.
Northern Spy, treated, Nos. 74, 75, 76, 77, 202, 205, 210, 212, 213, 215, 221, 223, 224, 225, 245.
TABLE—II. PERCENTAGE OF POTASH IN ASHES APPLIED.

<table>
<thead>
<tr>
<th>Year</th>
<th>Per ct</th>
<th>Year</th>
<th>Per ct</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>4.13</td>
<td>Seventh</td>
<td>3.24</td>
</tr>
<tr>
<td>Second</td>
<td>3.89</td>
<td>Eighth</td>
<td>4.39</td>
</tr>
<tr>
<td>Third</td>
<td>5.71</td>
<td>Ninth</td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td>5.71</td>
<td>Tenth</td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>1.38</td>
<td>Eleventh</td>
<td>5.06</td>
</tr>
<tr>
<td>Sixth</td>
<td>4.01</td>
<td>Twelfth</td>
<td>4.79</td>
</tr>
</tbody>
</table>

Since 100 pounds of ashes were applied to each tree annually these figures show the number of pounds of actual potash per tree each season. Thus, 42.31 pounds were applied per tree during the twelve years; 2,031 pounds per acre; an average of 169 pounds per acre for the twelve years. The amount of potash applied was much greater than is generally used in orchard practice, from 50 to 100 pounds per acre for apples being the common allowance.

Unfortunately the amounts of phosphoric acid and lime in the ashes used were not determined. But since the amount of phosphoric acid found in ashes varies from 1 to 2 per ct., 1½ per ct. being a fair average, we can assume that 1½ pounds of phosphoric acid were applied per tree each year, or 72 pounds per acre. The average analysis of commercial wood ashes shows them to contain 32 per ct. of lime, so that there was probably added about 32 pounds of lime per tree annually, or 1,536 pounds per acre. These amounts are in excess of those commonly thought to be necessary per acre for apples, and therefore this experiment has to do with phosphoric acid and lime as well as the potash in the wood ashes. It is true that phosphoric acid in ashes becomes available slowly. But its effects should be seen in twelve years, especially since the conditions, cultivation and the plowing under of cover crops, were favorable for its becoming available.

It is held by some that the apple does best on a slightly acid soil and it may be claimed that in this experiment lime has hindered the action of the other ingredients. However, I can find no data to show that an alkaline condition of the soil brought about by lime hinders any specific function of potash or phosphoric acid in growing apple trees; nor that the lime
accompaniment could in any way nullify or obscure the action of these nutrients as to the yield or color of apples. In this connection it is worth noting that some of the best apple regions in the United States have limestone soils. Many fruit growers use lime in moderate quantities as a fertilizer for apples. From these considerations it may be assumed that lime in the quantities added did not have a deleterious effect on the yield or color of the apple in this experiment; on the contrary, it might be suspected that the lime was in part responsible for such beneficial effects as were noted.

While no tests to determine the acidity of the soil were made, it may be inferred, since all leguminous cover crops grew readily in the untreated plats, that the soil of the orchard is not strongly acid, for the clovers, in particular, do not thrive in an acid soil.

Acid phosphate was applied to the treated plats at the rate of 8½ pounds per tree during the last seven years of the experiment. With 48 trees per acre, there were, therefore, 408 pounds of the acid phosphate applied to each acre. The fertilizer was guaranteed to contain 14 per cent. of phosphoric acid (analysis proved it to contain approximately that much) and the amount of available phosphoric acid per tree each season was 1.19 pounds, or 8.33 pounds per tree in the seven years. This is equivalent to 399.84 pounds per acre, an average of 57 pounds per acre annually. The amount of phosphoric acid recommended for apples ranges from 30 to 60 pounds per acre. Adding to the above amount the phosphoric acid to be found in the wood ashes, approximately 72 pounds per acre, the total quantity is about 129 pounds per acre,—an abundance and to spare.

The phosphoric acid was applied as were the ashes—scattered broadcast in the spring over an area slightly greater than that covered by the branches of the trees; a disk harrow was used to work the fertilizer rather deeply into the soil.

THE RESULTS.

There are several standards of measurement as to the merit of any treatment to which a fruit tree is subjected; as, growth of wood; leaf-size and total leaf-area; the several qualities of
fruit, as size, color, texture of flesh and keeping quality; and such tree characters as hardiness, productiveness, bearing habit and longevity. That is, the health and vigor of the tree and the value of the product are proportional to these qualities and characters and especially as to the degree of agreement between them. A wholly reliable method of testing any treatment of a fruit tree should take all of the above features into consideration and a method of measurement lacking any considerable number of them, generally speaking, is faulty. Data can be given in this investigation only as regards fruit, and at first thought there may be objections to conclusions drawn from such data. But since yield and quality of fruit constitute the ultimate criterion of the value of any orchard treatment; and since tree characters are not so important with old trees as in this experiment; and since the data regarding fruit are unusually full and detailed, the lack of information regarding tree characters does not seriously lessen the value of the experiment.

It is true that a crop is an uncertain standard of measurement; for with the apple there is a tendency to biennial bearing; the accidental variations in the crop are large; there are marked individual differences in the trees as to yield; and the varieties differ greatly in bearing capacity. These uncertainties have been largely overcome in this investigation by taking an average for twelve years and by including five varieties in the experiment.

In harvesting the crops the yields of the trees were recorded separately in pounds and ounces for the firsts, seconds, culls, and total weights. This enables us to study the crops from the standpoints of weight of product and of average size, there being three grades as to size. Attention is called to these two quite different standards of measurement. Size of individual fruits is one of the best criterions of the vigor of a tree if there be the average number of fruits. Large, succulent fruits indicate, as a rule, rapid and vigorous growth. The number of fruits, however, is probably a more accurate index of the food used by a tree, and therefore of the exhaustion of the soil and
of the need of fertilizers; for it seems fairly well established that a small and possibly poorly developed fruit contains practically as much dry matter, which represents plant food, as a large fruit. In other words, fruits seem to increase in size chiefly by the enlargement of cells, the contents being largely water, rather than by the multiplication of cells, a process seemingly requiring more solids.

YIELD OF FRUIT.

The yield of fruit is shown in Table III. The average yield per tree is given for each variety for the twelve years and the annual average per tree for the whole period. Fortunately the period during which the experiment was carried on was one of extreme fruitfulness for the apple in western New York and some fruit was harvested in each of the twelve years, excepting in 1903, giving a high average of productiveness for the orchard during the period.

Table III.—Average Yield of Apples Per Tree, With and Without Applications of Potash and Phosphoric Acid.

<table>
<thead>
<tr>
<th>Year</th>
<th>Baldwin</th>
<th>Fall Pippin</th>
<th>Roxbury</th>
<th>R. I. Greening</th>
<th>Northern Spy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1893</td>
<td>a few</td>
<td>none</td>
<td>0.08</td>
<td>2.01</td>
<td>1.57</td>
</tr>
<tr>
<td>1894</td>
<td>2.57</td>
<td>2.94</td>
<td>0.74</td>
<td>0.58</td>
<td>6.44</td>
</tr>
<tr>
<td>1895</td>
<td>6.88</td>
<td>9.81</td>
<td>5.43</td>
<td>3.94</td>
<td>6.89</td>
</tr>
<tr>
<td>1897</td>
<td>3.29</td>
<td>2.69</td>
<td>1.41</td>
<td>1.52</td>
<td>12.47</td>
</tr>
<tr>
<td>1898</td>
<td>8.22</td>
<td>8.02</td>
<td>2.96</td>
<td>2.70</td>
<td>9.98</td>
</tr>
<tr>
<td>1899</td>
<td>2.86</td>
<td>5.06</td>
<td>6.36</td>
<td>2.40</td>
<td>8.48</td>
</tr>
<tr>
<td>1900</td>
<td>17.82</td>
<td>15.62</td>
<td>13.96</td>
<td>10.38</td>
<td>15.20</td>
</tr>
<tr>
<td>1901</td>
<td>1.38</td>
<td>1.60</td>
<td>2.60</td>
<td>1.16</td>
<td>2.02</td>
</tr>
<tr>
<td>1902</td>
<td>16.08</td>
<td>13.78</td>
<td>11.94</td>
<td>10.62</td>
<td>19.90</td>
</tr>
<tr>
<td>1903</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual average per tree</td>
<td>8.78</td>
<td>8.50</td>
<td>7.23</td>
<td>6.18</td>
<td>11.16</td>
</tr>
</tbody>
</table>


In order to make comparisons of the annual averages per tree the figures given by Beach in Bulletin No. 140 for the first five years of the experiment are published as Table IV.

**Table IV.—Annual Average Yield of Apples per Tree for Five Years, With and Without Applications of Potash and Phosphoric Acid.**

<table>
<thead>
<tr>
<th>Years</th>
<th>Baldwin</th>
<th>Fall Pippin</th>
<th>Roxbury</th>
<th>R. I. Greening</th>
<th>Northern Spy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treated</td>
<td>Un-treated</td>
<td>Treated</td>
<td>Un-treated</td>
<td>Treated</td>
</tr>
<tr>
<td>1893-1897..</td>
<td>Bu. 7.66</td>
<td>Bu. 7.91</td>
<td>Bu. 5.66</td>
<td>Bu. 5.56</td>
<td>Bu. 7.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bu. 11.59</td>
<td>Bu. 8.69</td>
<td>Bu. 7.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bu. 9.93</td>
<td>Bu. 6.53</td>
<td></td>
</tr>
</tbody>
</table>

The annual averages showed, at the end of the first five years, an increased average yield per tree for Fall Pippin, Roxbury, Rhode Island *Greening* and Northern Spy and a decrease for the Baldwin. The differences are shown in Table V.

**Table V.—Increased Yields on Apple Plats Treated With Potash and Phosphoric Acid, Calculated at the End of Five Years.**

<table>
<thead>
<tr>
<th>Name</th>
<th>Annual average increase per tree</th>
<th>Rate per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Pippin</td>
<td>Bu. 0.10</td>
<td>Bu. 4.8</td>
</tr>
<tr>
<td>Roxbury</td>
<td>Bu. 2.90</td>
<td>139.2</td>
</tr>
<tr>
<td>R. I. Greening</td>
<td>Bu. 0.05</td>
<td>2.4</td>
</tr>
<tr>
<td>Northern Spy</td>
<td>Bu. 3.40</td>
<td>163.2</td>
</tr>
<tr>
<td>Baldwin</td>
<td>Bu. -0.28</td>
<td>-13.4</td>
</tr>
</tbody>
</table>

The results at the end of the twelve-year period are quite different, having changed the negative result for the Baldwin, as shown in Table V, to a positive one; and the positive result of the Rhode Island *Greening* to a negative one. Differences in yields for the twelve years are shown in Table VI.
TABLE VI.—INCREASED YIELD ON APPLE PLATS TREATED WITH POTASH AND PHOSPHORIC ACID, CALCULATED AT THE END OF TWELVE YEARS.

<table>
<thead>
<tr>
<th>Name</th>
<th>Annual average increase per tree</th>
<th>Rate per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Pippin</td>
<td>1.05 Bu.</td>
<td>50.4 Bu.</td>
</tr>
<tr>
<td>Roxbury</td>
<td>2.65</td>
<td>127.2</td>
</tr>
<tr>
<td>R. I. Greening</td>
<td>-0.34 Bu.</td>
<td>-16.3</td>
</tr>
<tr>
<td>Northern Spy</td>
<td>2.55</td>
<td>122.4</td>
</tr>
<tr>
<td>Baldwin</td>
<td>0.28</td>
<td>13.4</td>
</tr>
</tbody>
</table>

A very interesting fact is brought out in Table VII, namely, that both the treated and the untreated plats increased markedly in yield from 1893 to 1904 and that the productiveness of the orchard was for the treated plats 1.13 times, and the untreated plats 1.17 times as great in the second six-year period of the experiment as in the first six-year period, notwithstanding the facts that in 1903 in the second period not an apple was borne; that the 1896 crop, which came in the first period, was one of the most remarkable crops in quantity of fruit ever known in western New York. There can be but one explanation: Prior to 1893 the orchard was in sod, but during the continuance of this experiment it has been kept under cultivation and seemingly grew much more productive under the treatment.

TABLE VII.—SUM OF THE AVERAGE YIELDS OF APPLES WITH AND WITHOUT APPLICATIONS OF POTASH AND PHOSPHORIC ACID.

<table>
<thead>
<tr>
<th></th>
<th>1893</th>
<th>1894</th>
<th>1895</th>
<th>1896</th>
<th>1897</th>
<th>1898</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated, bushels</td>
<td>10.21</td>
<td>23.80</td>
<td>33.98</td>
<td>115.77</td>
<td>28.59</td>
<td>32.22</td>
</tr>
<tr>
<td>Untreated, bushels</td>
<td>5.37</td>
<td>16.28</td>
<td>33.17</td>
<td>102.42</td>
<td>23.47</td>
<td>24.70</td>
</tr>
</tbody>
</table>

TABLE VII.—(Continued).

<table>
<thead>
<tr>
<th></th>
<th>1899</th>
<th>1900</th>
<th>1901</th>
<th>1902</th>
<th>1903</th>
<th>1904</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated, bushels</td>
<td>24.14</td>
<td>70.54</td>
<td>9.14</td>
<td>75.16</td>
<td></td>
<td>98.74</td>
</tr>
<tr>
<td>Untreated, bushels</td>
<td>17.74</td>
<td>59.96</td>
<td>6.18</td>
<td>70.90</td>
<td></td>
<td>87.18</td>
</tr>
</tbody>
</table>
A study of the yields shown in these tables gives only uncertainty as to the effect produced by the fertilizers. If we regard the varieties separately, there are but two of the five varieties, Roxbury and Northern Spy, in which the effect has been sufficiently great to be looked upon as outside the range of variation; when we consider the varieties collectively the average annual gain per tree, 1.24 bu., is not great enough to be of practical importance. It must be noted, too, that the results obtained at the end of the five-year period, and those of the twelve-year period, are reversed with two of the five varieties and very materially changed with the other three.

Let us calculate the financial gain from the use of the fertilizers. Taking the sum of the gains and losses for the five varieties, for a hypothetical five acres, and we have in round numbers an annual gain of 99 barrels, including firsts, seconds and culls. At $1 per barrel, a fair average for twelve years for the three grades, we have $99 greater income from the treated five acres than from the untreated. With potash and phosphoric acid at five cents per pound each, the value of the fertilizer applied is $74.50 and we have a gain of but $24.50, not counting the work of handling, applying and working in the fertilizers to five acres of orchard, which practically offsets the gain. So that in practice, if not strictly in fact, the results from the fertilizers as to yields have been negative.

COLOR OF FRUIT.

It is commonly thought that out of the baker's dozen of elements made use of by plants, potash is the one which gives color to fruits. The statement is not infrequently made, too, that phosphoric acid has a decidedly beneficial effect on the color of fruit. This phase of the present experiment is therefore approached with some interest. In the Station orchard apples do not color well and if the addition of these fertilizers would heighten color their use might be desirable, even though there was no great gain in yield. On sandy soils, apples as a rule
take on their brightest colors, while on clay they run to duller hues. Because of their influence on color, potash and phosphoric acid are thought to be especially valuable on clay soils. The clay soil of the Station orchard was, therefore, a very favorable one upon which to try these substances to influence color.

The records for the twelve years for the varieties in question run as follows:—

1893. Slight improvement was noted in the color of all the varieties on the treated sections. Even the Roxbury was smoother and more highly colored on the treated than on the untreated section.

1894. Fall Pippins were smoother and fairer on the treated plats. Baldwins showed but little difference and that in favor of the untreated trees. Rhode Island Greenings had a riper appearance, more yellow and a tinge of red on treated plats. No difference discernible with Northern Spy and Roxbury. The results for this year were not at all uniform.

1895. Effects were not more noticeable for this season than in the previous one, Rhode Island Greenings and Northern Spys showing best color in untreated plats and Baldwins and Roxburys highest colored in treated plats; no difference noted between the plats of Fall Pippins.

1896. Colors developed as well on untreated plats as on treated.

1897. Crop comparatively small and poorly colored on both treated and untreated plats without noticeable difference.

1898. Effects not at all uniform, the product of the trees in the same plats differing as much as the products from different plats.

1899. Slight improvement in color of Baldwins and Northern Spys, the red sorts, no difference in Rhode Island Greening, Fall Pippin and Roxbury, the green varieties.

1900. No differences could be noted.

1901. Small crop of undersized fruit all poorly colored and no difference in favor of either set of plats.
1902. All of the treated plats showed more brilliant colors, though the differences could scarcely be noted in the green varieties.

1903. No crop.

1904. Differences slight and variable and not to be counted in favor of either treated or untreated trees.

Taken as a whole, the results are disappointing. They lack uniformity and were not decided enough in a sufficient number of the twelve seasons to enable us to state that the addition of the substances applied heightened the color of apples under the conditions of this experiment. The effects varied not only from season to season, but varieties varied greatly in some seasons, and in others the same variety would color differently in plats receiving the same treatment. When we consider the number of factors which are known to influence color in fruit we cannot assume with any degree of certainty that the results set forth above show that the addition of these fertilizers changed the color of the fruit in this experiment in any season; thus, exposure to light; the intensity of the light; amount of foliage on the tree; the healthfulness of the foliage; the amount of stored food in the plant; soil heat; the texture of the soil; all of these, besides potash and phosphoric acid, have an influence. The relations of these factors are so intricate that it is almost impossible to separate them in an experiment like this, and especially as the differences were so slight.

A comparison of the color data with meteorological data for the twelve-year period shows that the treatment seemed to have an influence in coloring fruit only in those years when the apple did not develop well, as in 1893 and 1902; and that in other seasons, as in 1896, 1900, 1904, when climatic conditions were favorable to the development of fruit and foliage, the coloring was as nearly perfect on the untreated as on the treated plats.

APPLICATION OF RESULTS.

The returns obtained in this twelve-year experiment are negative from a practical standpoint. This experiment shows that
it is not profitable to apply potash, phosphoric acid, or lime to the soil of the Station orchard. Fifty-seven years of orchard cropping has not reduced this soil to the condition where it needs a "complete" fertilizer, yet the leguminous cover crops plowed under in the orchard have usually produced beneficial effects the same or the next season. This seems to show that the orchard is having a one-sided wear. It needs nitrogen, or humus, or the physical condition to be obtained by plowing under organic matter. It would be an assumption to say whether it is the food, or the condition of the soil brought about by the organic matter, or both, that has proved beneficial when cover crops were plowed under.

"Potash for fruits" has been the cry for so long that many fruit growers are misled as to its use. It is true that the "out-go" of potash from the soil is relatively great, as shown by analyses, and if the soil lacks this ingredient, trees are not fruitful. But it is becoming more and more apparent that in many orchard soils potash is more abundant, or more available, or is less needed by the trees, than was formerly thought. Orchard practice, as well as the present experiment, has demonstrated that the plea for potash in orchards may not always be founded on a real need.

It must not be concluded, because the effects from the fertilizers applied were scarcely apparent in the Station orchard, that they would be ineffectual in all orchards, or necessarily for all time in this orchard. Plants require food, and the fact that certain nutrients added to this soil gave no results must mean that this particular soil contained an abundance of the elements added when the experiment was begun. Since, however, the soil of the Station orchard is an average piece of land for western New York—no better, no worse—there must be many other orchards in the State that do not need these fertilizers. In view of the fact that fertilizers are now very generally used in growing apples, it may be that considerable sums of money are wasted in buying and applying fertilizers which are not needed.
The fertilizers that have been missapplied to orchards have not been absolutely thrown away. The phosphoric acid put in the soil will remain stored up for a period of years; the potash will remain for a few years at least; and the lime is of more or less permanent value in the soil. Meanwhile it is possible that all of these compounds will have a beneficial effect on the cover crops grown in the orchard. Still, it is not profitable to buy fertilizers and store them in the soil in this way.

Since the ordinary farm and garden crops on the Station grounds, on soils quite similar to that upon which this experiment was carried on, show more or less marked beneficial effects from the use of potash and phosphoric acid fertilizers, it may be assumed that, during the fifty-seven years this orchard has been growing, general farming has been more exhaustive of the elements added in this experiment than have the apple trees. There are many facts that lead us to assume that the apple does not quickly exhaust a soil, but to the contrary wears a soil but little. This experiment suggests that such may be the case, but of course does not prove it; for the question is a complicated one, involving many factors not here considered.

The practical application of the information obtained by this experiment is, that the apple grower should not apply manures in quantity until he has obtained some evidence as to what food elements, if any, are needed in his soil. Good evidence in this direction is furnished by the trees themselves. So long as trees are growing well, adding a fair amount of new wood each year, and producing good crops of well-colored fruit, it may be taken for granted that they need no additional food from fertilizers. Should the growth and behavior of the trees be otherwise, it may be suspected that they need more, or other foods, and experiments should be set on foot to determine what and how much.
PLAN FOR FERTILIZER EXPERIMENT.

The following is a brief plan whereby a man may determine, in some measure at least, what fertilizers his orchard needs. The plan is adapted from a fertilizer experiment which has now been running for ten years in a young apple orchard on the Station grounds.

The trees selected for this experiment should be of the same variety and age and should stand in a soil as uniform in texture and fertility as the orchard affords. Unless one has positive proof that the trees do not need any one or more of the three elements we commonly supply in fertilizers, he should make use of all of them on his experimental plats. There should be a sufficient number of trees in each plat to offset individuality in the trees. Five trees for each plat is probably the least number that can be used with any degree of accuracy. There should be six or seven plats. For the average orchard in western New York, the following fertilizers might be tried:—

On Plat 1, use stable manure to supply nitrogen. Manure sufficient to supply 50 pounds of nitrogen to the acre per year would be a fair amount. On the average, according to analyses for our experiments, this would take about 7½ tons of well-rotted stable manure per acre. In an orchard where the trees stand 40 feet apart, this amount means about 400 pounds per tree.

On Plat 2, use a phosphate fertilizer in sufficient amount to supply 50 pounds of phosphoric acid per acre per year. A good recommendation is, 360 pounds of 14 per ct. guaranteed acid phosphate per acre, or 13 pounds of the fertilizer per tree.

On Plat 3, apply muriate of potash, guaranteed 48 per ct. to 52 per ct. actual potash. Apply 100 pounds of the potash per acre, which would require, of 50 per ct. actual potash, 200 pounds of the muriate of potash per acre, or 8 pounds per tree.

On Plat 4, combine the acid phosphate and the muriate of potash in the amounts prescribed for Plats 2 and 3.

On Plat 5, use a "complete" fertilizer, consisting of nitrogen as applied in Plat 1, and of phosphoric acid and potash as
applied in Plat 3. Or, for the stable manure, substitute dried blood and nitrate of soda. The former may be had with a guaranteed analysis of from 9 per ct. to 12 per ct.; the latter contains from 15 per ct. to 16 per ct. of nitrogen. The following amounts of these two substances should be applied: 350 pounds of dried blood per acre, or 12.84 pounds per tree; and 100 pounds of nitrate of soda per acre, or 3.67 pounds per tree.

Plat 6 should be a check. It is desirable to have two control plats, though, as the number of plats is increased, the work of the experiment is greatly increased.

If thought desirable to test the influence of lime, duplicate Plat 5 with the addition of 25 pounds of good stone lime per tree, which is to be applied unslaked.

Some care should be exercised in applying the fertilizers. The best time, all things considered, is spring, as soon as the ground can be worked. It might be well to apply the fertilizers containing nitrogen at a later time. The fertilizers should be weighed as accurately as possible. Spread broadcast about the tree over an area slightly greater than that covered by the branches of the tree. In cultivated orchards the commercial fertilizer should be harrowed in and the manure plowed under.

If the results are to be at all conclusive, such an experiment should run several years. It is not impossible in the average orchard to accurately weigh or measure the crop at harvest time to determine the relative value of the different treatments. It is not sufficient in packing to keep count of the number of barrels of marketable fruit from each plat; culls and windfalls should be accounted for.

It will be urged that this plat experimentation will be entirely out of the question for the busy fruit grower. The objection is not well founded. The plats can be laid out, the materials weighed, and all plans made for such experimentation in the winter, so that the actual work in the spring need not be great.

Such a simple experiment as has been outlined here may give results of financial value; at the same time it is true investiga-
tion and should stimulate the spirit of investigation to the great
good of the fruit grower himself. If such investigations were
developed among fruit growers as a body, in all phases of their
work, the industry would soon be revolutionized.

CONCLUSION.

The most important lessons taught by the experiment here
recorded are: That an orchard soil may not need potash, phos-
phoric acid, nor lime, even though the soil may have been
cropped a half century; that in a soil which produces apples
of poor color potash and phosphoric acid may not improve the
color; and that the apple does not seem to be as exhaustive of
soil fertility as farm crops. The experiment suggests, as well,
that to assume without definite knowledge that a tree needs this
or that plant food often leads to the waste of fertilizing mate-
rial; and that in the matter of fertilizing an orchard a fruit
grower should experiment for himself, since an orchard’s need
of fertilizer can be determined only by the behavior of the trees
when supplied with the several plant foods.