CHLOROSIS OF TREES

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(WITH ONE FIGURE)

Introduction

Chlorosis is a condition of the leaf in which chlorophyll fails to develop normally. Bourcart (1) states that this pathological condition is known as jaundice when caused by want or excess of water, and chlorosis when it is due to lack of iron or potash. An excess of carbonate of lime in the soil, insufficient nourishment, defective condition of the roots, a pathological condition of the whole tree, are some of the many causes which may produce chlorosis. When due to lack of iron, chlorosis has some analogy to the anemia of man.

Much has been published on the causes and treatment of chlorosis. No attempt is made to cite all the literature published, but a few citations are given to indicate the extent of its occurrence, and its treatment.

Bourcart (1) states that an excess of carbonate of lime is the predominating cause of chlorosis of trees with seed pips, such as the pear, and more especially of the vine. He recommends green vitriol for both trees and vineyards. Kelley (7) found that an excess of manganese in the soil was responsible for the chlorotic condition of pineapples, as well as some other plants in Hawaii. Johnson (6) confirmed Kelley's finding and found that chlorotic pineapples were restored to normality by spraying with an iron sulphate solution.

Wallace and Mann (8) found considerable difference in the chemical composition of the ash of chlorotic and normal fruit trees. The percentage of ash in the dry matter, with one exception, was higher in the chlorotic than in the normal leaves.

The Chemistry Department of the Idaho Agricultural Experiment Station (5) associates the chlorosis of trees and shrubs with high calcium carbonate soils even though a considerable amount of iron is present. Giles (3) found that the chlorosis of pineapples in Porto Rico was the result of malnutrition, caused by an excessive amount of calcium carbonate in the soil. Giles and Carrero (4) report that chlorotic rice plants may be restored to their normal color by spraying with ferrous sulphate.

Burgess and Pohlman (2), in studying the cause of citrus chlorosis, found that improper irrigation was a factor. Spraying the trees with an iron salt solution did not give beneficial results.

1 Contribution from Montana State College, Agricultural Experiment Station, Paper no. 14, Journal series.
It is evident, from the literature cited, that numerous plants become chlorotic when grown in soils high in calcium carbonate, or manganese, or when improperly irrigated.

The first investigation of chlorosis at the Montana Station dates back to the spring of 1908, at which time the Departments of Chemistry and Botany treated a chlorotic cottonwood tree, growing on the College campus, with a 0.25 per cent. solution of ferrous sulphate. The tree was about ten inches in diameter and four liters of the iron solution were injected into the trunk. Improvement was rapid and the tree had fully recovered by the following spring. Since that time several cottonwood trees have been treated with a solution of ferrous sulphate with equally good results. A slight burning of the leaves occurred when a 0.5 per cent. solution was used and as much as four liters applied to trees eight to ten inches in diameter.

An investigation of apple trees was started in 1914 when the writer's attention was called to a condition affecting the orchards in certain sections of the Bitter Root Valley, the fruit section of the State. At the time of inspection the trees were making poor growth and the leaves were small and yellowish in color. It was found, on taking soil samples near the trees showing abnormal conditions, that the subsoil consisted quite largely of sand and gravel of various sizes cemented together by calcium carbonate. It was almost impossible to go through this formation with a pick or a crowbar. The average analyses of several samples gave the following results: First foot, nitrogen, 0.095 per cent., calcium 8.05 per cent., phosphorus 0.105 per cent., and potassium 0.29 per cent.; second foot, nitrogen 0.057 per cent., calcium 14.62 per cent., phosphorus 0.083 per cent., potassium 0.20 per cent., and iron 0.35 per cent.

The analyses indicate that the soil was fairly well supplied with nitrogen and phosphorus, with an abnormally large supply of calcium and a rather low amount of potassium. The percentage of iron was considerably less than is found in fertile soils of the state.

No further investigation was made until the fall of 1922, when our attention was again called to this trouble by the State Horticulturist, who pointed out that chlorosis in the Bitter Root Valley might prove as injurious to that fruit section as had the fruit-tree leaf-roller, which had just made its appearance and was doing considerable damage. It was found that the greatest injury was occurring in a high-lime soil area.

In the orchard selected for conducting the experiments many of the trees were not only failing to make normal growth, but several were dead. The leaves on the chlorotic trees were small and yellow, and the trees had made little or no growth. The poor condition of the trees had been attributed by some people to high water-table and a water-logged condition, while others thought it was the result of too much alkali in the soil. How-
ever, a hole dug five feet deep near a chlorotic tree failed to reach the water-
table and an analysis of the soil revealed the presence of very little alkali
salts, not enough to cause tree injury. An average analysis of the second
foot of soil showed a calcium content of 14.53 per cent. and 1.0 per cent. of
iron. The samples were not analyzed for nitrogen, phosphorus, and potas-
sium, since we believed that they would not vary materially from the
analyses given.

An inspection of this orchard, made a few days after it had been irri-
gated, showed an apparent water-table at a depth ranging from two to three
feet. This condition, while only temporary, undoubtedly had the effect of
decreasing the supply of available nitrogen, which would result in lightening
the color of the leaves.

Treatment of trees

After making a study of the soil and trees it was decided that the
chlorotic condition was probably caused by too much lime in the soil, and
that treatment with iron should prove beneficial. The first treatments were
made in August, 1922, when 500 cc. of a 0.25 per cent. solution of ferrous
sulphate were injected into each of two trees with yellow leaves that had
failed to make a normal growth. A hole, one-fourth inch in diameter, was
bored into the sap wood of the trunk of the tree, into which an L-shaped
gas pipe was fitted. One end of a rubber tube was slipped over the end
of the gas pipe and the other end was attached to a wide-mouthed bottle con-
taining iron sulphate solution. The bottle was inverted and hung to a
branch of the tree about four feet above the gas pipe in the trunk. To
admit air into the bottle a U-shaped glass tube was used, one end being
pushed through a rubber stopper to the bottom of the bottle and the other
end projecting to a little above the bottom on the outside. By this method
the iron solution was injected into the tree. Two other trees were treated
by digging a circular trench about one foot deep and four feet from the
trunk. Five pounds of ferrous sulphate were scattered in the trench, after
which it was covered with earth and watered. Another set of two trees
was sprayed with a 0.5 per cent. solution of ferrous sulphate. Several
other trees showing a decidedly chlorotic condition were treated with a
complete fertilizer to determine if a lack of plant food might be the cause.

Results

An inspection made in the fall showed that neither the soil application
nor the spray treatment had improved the chlorotic condition of the trees.
The injection of ferrous sulphate had only slightly improved the color of
the leaves formed at the time of treatment, but the leaves which had formed
after treatment were of a green color and normal in appearance. Figure 1
PLANT PHYSIOLOGY

gives a fair idea of the difference in the appearance of the leaves before and after treatment. The upper three leaves were formed after treatment.

Fig. 1. Leaves of apple, showing recovery from chlorosis. The upper three leaves produced after treatment.

An inspection made the following June showed no beneficial effect from the spray, soil or fertilizer treatment, while the two trees into which ferrous sulphate had been injected were normal in appearance and remained so.

From these results it was evident that a solution of ferrous sulphate injected into a tree would restore the leaves to their normal color. Another test was undertaken in May, 1924, when twelve trees with yellow leaves were treated with ferrous sulphate or ferric nitrate. In some cases the iron salts were injected into the trunk of the tree for the purpose of restoring the whole tree to normal condition, while in other instances, the injection was made into one branch of the tree so that a comparison could be made between the color of the leaves on the treated and the untreated branches. In addition to injecting an iron solution into the tree, a one-half inch hole, sloping downward, was bored into the tree and either ferrous sulphate or ferric nitrate salts inserted and water added until the salts were dissolved. Another yet simpler method of supplying the iron, one that any orchardist could use, was also tried, viz., driving iron nails into the trees. Heavy finishing nails, about one to one and one-fourth inches long, were used for this purpose. Care was used in driving the nails into the tree to avoid injuring the bark, and a nail-set was used to drive the nails so that the heads would be completely under the bark. In the case of branches some eight or ten nails were driven in. Where the nails were driven into the trunk as many as fifteen or twenty were used. The nails did not give as rapid
<table>
<thead>
<tr>
<th>TREE NUMBER</th>
<th>CONDITION OF TREE</th>
<th>TREATMENT</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All leaves were yellow, general condition bad</td>
<td>Worst branch treated with 2 gm. Fe(NO₃)₃ crystals</td>
<td>Some improvement during summer. Following year the leaves were all yellow. Tree pulled</td>
</tr>
<tr>
<td>2</td>
<td>Leaves were yellow</td>
<td>2 gm. FeSO₄ crystals put into hole in trunk</td>
<td>Recovery was complete</td>
</tr>
<tr>
<td>3</td>
<td>Leaves were yellow</td>
<td>3 gm. Fe(NO₃)₃ crystals put into hole in trunk</td>
<td>Recovery was complete</td>
</tr>
<tr>
<td>4</td>
<td>Decidedly chlorotic</td>
<td>Worst branch treated with 3 gm. Fe(NO₃)₃ crystals</td>
<td>Branch recovered, remainder of tree remained chlorotic</td>
</tr>
<tr>
<td>5</td>
<td>Part of the leaves were yellow</td>
<td>30 cc. of 12.5 per cent. solution of Fe(NO₃)₃ injected into trunk</td>
<td>Recovery was complete</td>
</tr>
<tr>
<td>6</td>
<td>Decidedly chlorotic</td>
<td>5 gm. FeSO₄ crystals put into one branch. One year later, iron nails driven into trunk</td>
<td>Treated branch recovered first. Last inspection found an almost complete recovery</td>
</tr>
<tr>
<td>7</td>
<td>Decidedly chlorotic</td>
<td>Worst branch treated with 3 gm. FeSO₄ crystals. One year later iron nails driven into trunk</td>
<td>Treated branch recovered first. Balance of the tree recovered slowly, but completely</td>
</tr>
<tr>
<td>8</td>
<td>Decidedly chlorotic</td>
<td>500 cc. 0.25 per cent. solution of Fe(NO₃)₃ injected into one branch. One year later iron nails driven into trunk</td>
<td>Slight improvement the first year. Last inspection found the tree still chlorotic</td>
</tr>
<tr>
<td>9</td>
<td>Worst physical condition of any of the trees treated</td>
<td>First, 5 lb. FeSO₄, second, 500 cc. 0.25 per cent. solution FeSO₄ injected into one branch. Third, complete fertilizer added to soil. Fourth, 5 gm. FeSO₄ crystals put into hole in trunk. Fifth, iron nails driven into trunk</td>
<td>Slow, but complete recovery</td>
</tr>
<tr>
<td>10</td>
<td>Decidedly chlorotic</td>
<td>500 cc. 0.25 per cent. solution of FeSO₄ injected into one branch. One year later iron nails driven into trunk</td>
<td>Recovery was complete</td>
</tr>
<tr>
<td>11</td>
<td>All leaves were yellow</td>
<td>2 gm. FeSO₄ crystals put into trunk</td>
<td>Recovery was complete</td>
</tr>
<tr>
<td>12</td>
<td>All leaves were yellow</td>
<td>500 cc. 0.25 per cent. solution of FeSO₄ injected into one branch</td>
<td>Leaves on treated branch became normal, those on remaining branches remained chlorotic</td>
</tr>
</tbody>
</table>
action as when the iron was put into the tree in solution, yet the final results were as satisfactory. The accompanying table describes the condition of each tree at the time of treatment, May 20, 1924, the kind of treatment and the results obtained.

In addition to the trees described in the table, four trees were selected for treatment with iron nails only. On June 1, 1925, iron nails were driven into the trunks of the trees. The leaves on all of the trees were yellow at the time of treatment. A slight improvement was noted when inspected on August 18, 1926. On June 21, 1927, when last inspected, recovery was complete.

**Summary**

Cottonwood trees are susceptible to chlorosis, which can be overcome by treatment with iron salts.

Apple trees grown in high lime soils are subject to chlorosis. The lime evidently prevents the iron in the soil from becoming available. The fact that, in most cases, iron salts restored trees to normality indicates a lack of *available* iron in the soil.

Spraying with a 0.5 per cent. solution of ferrous sulphate, or applying ferrous sulphate to the soil, did not improve the chlorotic condition of the trees.

Treatment internally with iron salts, both as dilute solutions and as solid salts, gave beneficial results.

Iron nails driven into the trunks of four trees gave beneficial results. The recovery of chlorotic trees treated with iron nails was not so rapid as when treated with iron salts, although it seemed to be as effective. The ease of application should appeal to orchardists.

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**LITERATURE CITED**


