5-1930

Circular No. 85 - Chlorosis Yellowing of Plants: Cause and Control

F. B. Wann

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CHLOROSIS
YELLOWING OF PLANTS
Cause and Control

F. B. WANN

Chlorotic pear tree second year after injection of iron into right side. Left side not treated.

Agricultural Experiment Station
Utah State Agricultural College
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CHLOROSIS'
YELLOWING OF PLANTS
Cause and Control
F. B. WANN

CONTENTS

<table>
<thead>
<tr>
<th>Nature of Plant-foods</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Coloring Material of Plants</td>
<td>3</td>
</tr>
<tr>
<td>Effect of Chlorosis on Plant Growth</td>
<td>4</td>
</tr>
<tr>
<td>Causes of Chlorosis</td>
<td>5</td>
</tr>
<tr>
<td>Chlorosis Due to Lack of Minerals</td>
<td>6</td>
</tr>
<tr>
<td>Chlorosis Caused by Excesses</td>
<td>7</td>
</tr>
<tr>
<td>Other Contributing Factors</td>
<td>8</td>
</tr>
<tr>
<td>Chlorosis in Utah</td>
<td>8</td>
</tr>
<tr>
<td>Treatment of Chlorosis</td>
<td>9</td>
</tr>
<tr>
<td>Mechanical Application of Iron</td>
<td>9</td>
</tr>
<tr>
<td>Soil Treatment</td>
<td>10</td>
</tr>
<tr>
<td>Conclusions</td>
<td>11</td>
</tr>
</tbody>
</table>

Chlorosis is a disease of plants, the characteristic symptom of which is the yellowing of the leaves. The disease is of sporadic but widespread distribution in Utah and the aggregate losses caused by it are undoubtedly greater than those of any other one disease. Not only are many plants killed, or weakened to such an extent that only inferior crops are produced, but many areas of land which might otherwise support profitable orchards have been abandoned or planted to other crops because of the disease.

Chlorosis differs from some of the more popularly recognized plant diseases in that it is not produced by fungi or bacteria but is due to a disturbance in the normal nutrition of the plant. In this respect it is similar to such familiar animal or human diseases as beri-beri and rickets, which are definitely recognized as nutritional in cause. The nutritional relationship suggests that chlorosis does not spread from plant to plant as many of the parasitic diseases do, but that it will occur wherever plants are not receiving proper nourishment and that any plant may be susceptible to the disease under these conditions. In order to completely appreciate the conditions responsible for chlorosis and the effect of the disease on the plant itself, it is necessary first to understand a few fundamentals of plant nutrition.

NATURE OF PLANT-FOODS

Plants require two kinds of food substances: (1) Minerals and (2) energy-containing foods. Minerals enter into the composition of some

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2Associate Plant Physiologist

Acknowledgements.—The writer gratefully acknowledges the cooperation of Dr. B. L. Richards, Pathologist, and Prof. D. W. Pittman, Associate Agronomist, in the preparation of this circular.

Publication authorized by Director, April 26, 1930.
of the complex compounds found in the plant body, while the energy-containing foods supply energy for growth as well as the materials with which the body itself is largely constructed. It is commonly believed that the growing plant derives all its food from the soil, while in reality minerals only are so obtained. The energy-containing foods are manufactured by the plant itself.

This process of food manufacture consists essentially of the chemical union of water and carbon dioxide gas to form sugar and is brought about by sunlight acting through the green coloring material of plant leaves. The carbon dioxide gas is obtained from the air and enters the leaf directly through small breathing pores. Water is absorbed from the soil and carried up to the leaves. Neither the water nor the carbon dioxide contains energy, but in the process of their union a large amount of energy from the sunlight is stored in the resulting sugar. A considerable part of the sugar may be converted into starch, fats, oils, etc., which are stored for future use; the balance is used directly in growth, either in the construction of new plant parts or in supplying the necessary energy. Since the rate of growth, as well as the total amount of growth, is proportional to the amount of energy-containing food available it is evident that any condition which interferes with the manufacture of food will affect the vigor and size of the plant. One such condition is the failure of the leaves to produce their normal green color when suffering from chlorosis.

**GREEN COLORING MATERIAL OF PLANTS**

To the unaided eye the deep green color of a healthy plant appears to be uniformly distributed throughout the leaf. If, however, such a leaf is examined with a microscope it will be observed that the color is actually located in minute round bodies which are contained in the numerous box-like compartments of which the leaf is composed. These compartments or structural units of the leaf are called cells; each cell may contain from 50 to 100 or more color-bodies. Since a single leaf may be composed of several thousand cells, the number of color-bodies present is exceedingly large. Each color-body is a minute mass of living protoplasm floating in the living fluid of the cell and containing the green pigment called chlorophyll.

Chlorophyll is tremendously important in the process of food-manufacture, for without it the process cannot take place. Apparently, the sunlight acts through the chlorophyll in bringing about the combination of carbon dioxide and water to form sugar. Furthermore, it appears that in this activity of sunlight a part of the chlorophyll is destroyed. Thus, it is necessary for the color-bodies to continuously manufacture new chlorophyll to replace that which is used up. Otherwise, the leaf would gradually lose its green color entirely and the food-manufacturing process would cease. Anything, therefore, which interferes with this process will result in a gradual fading of the leaf color, first to light green, then to yellow, and finally to white. Thus, chlorosis is a diseased condition found in plant leaves.
which fail to produce the normal amount of chlorophyll. The condition may occur in practically all plants, affecting the entire plant or merely a portion of it. There are apparently several causes for chlorosis, each of which may produce characteristic symptoms in different plants. Varying degrees of severity may also be apparent. In all cases, however, the chief feature of chlorosis is a deficiency of the green color, or chlorophyll.

The evidences of the disease are usually quite apparent. In mild cases a pale green color of the entire leaf may be the only indication. As the disease increases in severity the color fades from the numerous areas of the leaf between the smaller veins. These areas, as well as the margins of the leaf, become yellowish, leaving only the larger veins green. Gradually the color fades from the veins until the entire leaf is yellowish. In the final stages the leaf becomes white, shrivels up, and drops off the plant. In plants which are regularly chlorotic, the new growth in the spring is much stunted with yellowish leaves which are small and thin.

EFFECT OF CHLOROSIS ON PLANT GROWTH

It is evident from the food-manufacturing process that the first effect of chlorosis on the plant is a reduction in the food-supply. Lack of plant-food results in slow growth, smaller leaves, shorter new twigs, and reduced root growth. If the chlorotic condition is severe and long-continued, the plant finally dies.

Actual measurements on the same individual plant show that the chlorotic leaves are smaller than the green leaves of the same age. In the case of a pear tree suffering from chlorosis in some of the limbs but with normal leaves on other branches (cover cut), such measurements showed a reduction of about 23 per cent in the size of the chlorotic leaves and about 13 per cent in the dry weight of such leaves. Similar data for apple leaves show that chlorotic leaves were 14 per cent smaller than normal green leaves and were reduced in weight by 25 per cent.

The diameter growth of pear and apple twigs has also been studied in some detail. The measurements obtained in these studies indicate that chlorotic twigs may produce only 40 or 50 per cent as much wood as formed by the twigs of normal trees.

In addition to these effects on the vegetative parts of the plant, the fruit is also considerably affected. Because of the shortage of food the fruit matures too early, is smaller, and is of poorer quality than normal. Finally, because of their weakened condition, chlorotic plants are more susceptible to fungous attack and to winter injury.

CAUSES OF CHLOROSIS

The yellowing of plant leaves which is the characteristic symptom of chlorosis may be produced by any one of a large number of causes. Although some of the parasitic diseases of plants may induce yellowing, typical cases of chlorosis occur in the complete absence of a parasite, being caused, therefore, by certain physical or chemical
factors outside the plant. The chief factors causing chlorosis are associated with nutrition of the plant. For normal chlorophyll production certain minerals must be available. These include nitrogen, magnesium, and iron. Other minerals, such as potassium, phosphorus, calcium, and sulphur are necessary for normal growth but they enter into other plant products, whereas nitrogen, magnesium, and iron are used directly in the formation of chlorophyll. The source of all minerals is in the soil.

Each mineral is absorbed by the plant independently and to be absorbed must be in solution in the soil water. The solubilities of the various minerals differ from each other; some are very soluble, others are only slightly soluble. In the soil water the solubility of a mineral may be affected by several factors, chief of which are the presence of other minerals and the soil reaction, that is, whether the soil is acid or alkaline. It is possible, therefore, for a mineral to be present in the soil in large quantity and still not be in solution in the soil water to any appreciable extent. In this case the mineral is said to be unavailable to the plant.

**Chlorosis Due to Lack of Minerals**

The most frequent cause of chlorosis is the lack of one of the essential mineral nutrients in the plant. This lack may be occasioned by the actual absence of the mineral in the soil or by the fact that the mineral, though present, is not in solution in the soil water and hence cannot be absorbed by the plant.

**Lack of Nitrogen.**—Plants grown in poor soil are usually light green in color, due in most cases to low nitrogen supply. The addition of certain nitrogenous fertilizers to old orchards or to trees on worn-out soils is frequently attended by increased chlorophyll production, as is evidenced by the darker green color of the leaves within a short time. On many of the light soils of the semi-arid west, especially where irrigation is practised, the nitrogen supply is probably lower than the needs of the plants and may be a contributing factor to the chlorotic condition found on these soils.

**Lack of Magnesium.**—Chlorosis due to lack of magnesium is probably not encountered in Utah. In other areas, notably certain sections of the Carolinas, magnesium is deficient in the soil; chlorosis is the natural result. The addition of sufficient magnesium to the soils to permit of normal chlorophyll production will correct this condition.

**Lack of Iron.**—The lack of iron in the plant is perhaps the most common and the most important cause of chlorosis. This condition is encountered in a great variety of plants and in widely separated regions. Chlorosis of grapes in France and Germany, of rice, sugar-cane, and pineapples in Hawaii, and of citrus fruits in the southwestern United States are notable examples which have received much attention from agricultural workers. In all these cases the lack of iron is caused by peculiar soil conditions which make the

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iron unavailable. The most frequent condition is that found in the so-called calcareous or lime soils of southern Europe, Porto Rico, Florida, and southwestern United States. These soils may contain just as much iron as do normal soils, but the iron is prevented from going into solution in the soil water because of the large amounts of lime present. Chlorosis occurs on these soils because plants fail to obtain enough iron for normal chlorophyll production. That the chlorotic plants are in reality suffering from a lack of iron is shown by the fact that when iron is injected mechanically into them they usually recover their normal green color. On the other hand, the addition of iron to the soil usually results in little or no benefit.

Where soils are acid in reaction, as in eastern United States, it is common practice to add lime to neutralize this acidity. Occasionally too much lime is applied, with the result that chlorosis is produced by the action of the lime on the solubility of iron. In Utah where practically all soils are high in lime and are already alkaline in reaction, it is not to be expected that additional lime would be of any benefit in preventing chlorosis. In fact, the opposite effect would be expected. In spite of these facts it has been suggested by some growers that the addition of lime would be beneficial. This is at best questionable, and as far as chlorosis is concerned would probably increase the trouble.

Chlorosis Caused by Excesses

In addition to the type of chlorosis caused by the lack of certain substances in the plant, there are cases where excess of other substances may also bring about yellowing of the leaves.

Excess Water-Supply.—Perhaps the most common explanation for chlorosis offered by the grower is that of "too much water". There seems to be a rather general popular belief that over-irrigation causes the yellowing. Over-irrigation was suggested as the cause of chlorosis by investigators in Idaho who were studying the effects of irrigation on apples. No data, however, were presented to substantiate this claim. In the case of seedlings of western yellow pine in Nebraska and Idaho chlorosis was definitely associated with high soil-water content. Recent experiments in Arizona indicate that citrus chlorosis can be controlled by proper irrigation methods. Early observations in France and Germany associated the appearance of chlorosis with cold, damp soil; they also tend to show that the disease is more prevalent during a damp spring season.

References:
While these general observations show that excess water is a contributing cause of chlorosis, it has not been established that this is the primary cause. There is no doubt that a flooded soil would accentuate the trouble through suffocation of the roots, but for any number of observations showing chlorosis on wet soils an equal or perhaps greater number would show the same trouble on well-drained soils. In a vineyard at Kaysville (Utah) chlorosis is most prevalent on the edge of a ravine and on a field which is never irrigated. In this case some cause other than excess water must be responsible.

Alkali Soils.—Severe cases of chlorosis are frequently encountered on alkali soils. The primary cause of the disease on such soils is difficult to determine because of the fact that more than one factor may be involved. In some instances the excess salts may effect the solubility of certain essential minerals in a manner similar to the effect of lime on the availability of iron. On the other hand, the accumulation of salts in the plant may interfere with the proper utilization of some of the absorbed nutrients. Whatever the explanation, the condition recognized as “alkali soil” undoubtedly aggravates the disease.

Other Contributing Factors

In addition to the factors which are primarily associated with soil conditions certain physical factors are known to cause chlorosis, chief of which are low temperature and lack of light. However, neither of these is of great importance under field conditions.

Low Temperature.—Scientific research has shown that plants exposed to low temperatures may become more or less chlorotic. Severe winter temperatures or late frosts may thus account for certain cases of chlorosis, but in most instances some other factor is the primary cause.

Lack of Light.—Light is one of the conditions necessary for chlorophyll formation. Plants grown continuously in the dark are yellow in color but will become green if brought into the light. While this type of yellowing does not occur under ordinary agricultural conditions, it is true that crowding of plants or trees may result in poor chlorophyll development or mild chlorosis in densely shaded portions of the plant.

CHLOROSIS IN UTAH

In view of the possible causes of chlorosis just discussed it is probable that no single factor is responsible for all the chlorosis in Utah. Excess water, alkali soil, and lack of specific mineral nutrients are no doubt the most important factors to be considered. The first two are usually more or less local and present specific and difficult problems for control. In the majority of cases, however, the most plausible explanation for chlorosis appears to be the lack of available iron in the soil due to the presence of considerable lime. This type of chlorosis can be successfully treated.
TREATMENT OF CHLOROSIS

Since chlorosis is primarily a result of disturbed nutrient relations, its treatment is based on entirely different principles than the treatment of diseases which are caused by the attack of bacteria, fungi, or insects. In the majority of cases in Utah it appears that the logical treatment is one which supplies the chlorotic plants with iron. There are two possible methods of attack: (1) The actual mechanical application of iron into or on the plant; (2) soil treatment to render the iron already present in the soil available to the plant. In both types of treatment the end in view is to replenish the supply of soluble iron inside the plant leaves so that the formation of the green coloring matter, or chlorophyll, may proceed.

Mechanical Application of Iron

Under the first method of attack at least two promising types of treatment may be suggested for rather diverse kinds of plants. These are (1) spraying and (2) injection.

Spraying Chlorotic Plants with Iron.—In the case of small plants such as shrubs, bushes, and annuals, which are not large enough for the injection treatment, the application of a solution of iron directly on the chlorotic leaves may be beneficial. In order to cover the surfaces of the leaves as thoroughly as possible, the solution should be applied as a spray. A variety of iron salts might be suggested for use, but commercial iron sulphate is easily obtainable, is cheap, and has given satisfactory results. The strength of the solution is highly important. For most plants a 5 per cent solution is satisfactory. This is prepared at the rate of 2 ounces of iron sulphate to 1 quart of water, or \( \frac{1}{2} \) pound to the gallon. A stronger solution than this is may cause injury to the foliage. The spray should be applied several successive times at intervals of a week or ten days.

The principle involved in this treatment is merely the direct absorption by the leaf cells of the iron applied in the spray. The efficiency of the treatment will depend upon the character of the application and to a considerable extent upon the nature of the leaf surface. Waxy leaves to which the spray does not readily adhere will probably not be benefited as much as will rough or hairy leaves.

Injection of Iron Salts into Woody Plants.—Woody plants, such as trees, grapevines, etc., can be treated for chlorosis by the injection of iron salts into the stem. This treatment consists essentially in boring a small hole into the wood, inserting the dry iron powder, and, sealing the hole over with wax. For small trees, 2 or 3 inches in diameter, a single hole bored with a \( \frac{3}{8} \) -inch wood bit to a depth of three-fourths inch and filled with the iron powder will usually be sufficient. For larger trees two or more injections should be made and holes spaced around the tree trunk at intervals of about 3 inches. This is important because in large trees the iron appears to be transported into only those limbs which are immediately above the point of injection. In mature fruit trees where three or four "scaffold"
branches are present it is advisable, therefore, to make injections below each of them.

Several different iron salts have been used with success in this type of treatment, but the most promising are iron citrate (ferric citrate) and iron phosphate (soluble ferric phosphate). These iron salts, in the form of flaky crystals, can be obtained at any drug store and should be ground to a powder for injection into the plant. They are not poisonous. The commercial iron sulphate should not be used in this type of treatment. When the hole is filled with the powdered iron it should be sealed over with a protective wax of some sort. Ordinary grafting wax is suitable for this purpose; for small stems the grafting tape may be used. Where a large number of treatments are to be made it has been found convenient to put the iron powder in ordinary medicine capsules. After first removing and discarding the cap the longer portion containing the iron can be inserted, open end inward, into the hole, which is then sealed over. The presence of the capsule does not interfere with the solution of the iron in the plant sap, while its use permits easy and rapid injection of the iron without loss. The cost of materials for these treatments is less than 1 cent an injection.

The principle underlying the injection method of treatment is simply the fact that certain forms of iron will dissolve in the sap of plants and be carried to the leaves in solution. Iron citrate and iron phosphate are two such forms. They are further characterized by the fact that they are not injurious to plants. The problem is merely to get the iron into the sap of the tree with as little injury as possible.

**Soil Treatment**

The other method of attack is that of soil treatment which will make the iron already present in the soil available. The extremely complex nature of the soil, however, places great difficulties in the way of accomplishing much by this method. Practically all Utah soils contain considerable lime and are distinctly alkaline as compared with the acid soils of the east and middlewest. The presence of lime prevents the soil from going into solution. To remedy this by soil treatment would require the addition of acid or acid-forming substances in large amounts. From the standpoint of general agricultural practice barnyard manure is probably the most promising acid-forming substance, for not only does it tend to counteract the lime but also adds nitrogen and greatly improves the physical properties of the soil. Ammonium sulphate and sulphur are also acid-forming. The application of any of these fertilizers may eventually produce beneficial results in the treatment of chlorosis and may be made in conjunction with either spraying or injection of iron. The soil treatment is especially applicable to strawberry plants.
1. In the process of food manufacture the green pigment of plant leaves plays an important part.

2. Under certain conditions in Utah the formation of this green pigment is interfered with, resulting in a yellowing which is called chlorosis. The disease seriously affects the food-supply and therefore the growth of plants.

3. The probable cause for most of this chlorosis is a lack of sufficient iron in the plant, a condition caused by certain soil relationships, notably the presence of considerable lime.

4. Treatment of the disease is directed toward replenishing the iron supply in the leaves.

5. Two methods of control are suggested:
   (1) The mechanical application of iron on the plant by spraying or by its injection into the plant body.
   (2) Soil treatment consisting of the addition of manure, ammonium sulphate, or sulphur to the soil.
CHLOROSIS—YELLOWING OF PLANTS

LIST OF AVAILABLE BULLETINS

122—Nature of the Dry Farm Soil of Utah.
128—Blooming Periods and Yields of Fruit in Relation to Minimum Temperatures.
132—Minor Dry-land Crops at Nephi Experiment Farm.
137—Quality of Home-grown Wheat vs. Imported Wheat.
139—Movement of Soluble Salts with Soil Moisture.
141—Variation in Minimum Temperatures due to Topography of a Mountain Valley in Relation to Fruit-growing.
143—Fruit Treet Root System—Spread and Depth.
144—Water Table Variations—Causes and Effects.
147—Alkal Content of Irrigation Waters.
150—Further Studies on Nitric Nitrogen Content of Country Rock.
152—Effect of Soil Moisture on Certain Factors in Wheat Production.
158—Soil Moisture Studies under Dry-farming.
159—Soil Moisture Studies under Irrigation.
160—Important Factors in Operation of Irrigated Farms.
161—Orchard Heating.
163—Composition of Irrigation Waters of Utah.
165—Labor Costs and Seasonal Distribution of Labor in Irrigated Crops.
167—Irrigation of Oats.
178—Irrigation of Barley.
181—Duty-of-Water Investigations on Coal Creek, Utah.
183—Water-holding Capacity of Irrigated Soils.
184—Farm Management Study of Great Salt Lake Valley.
185—Influence of Nitrogen in Soil on Azofication (Technical).
186—Irrigation Experiments in Sugar-beets.
187—Irrigation Experiments in Potatoes.
188—Maintaining the Productivity of the Soil.
189—Ridding the Land of Wild Morning Glory.
190—Corn Silage in the Dairy Ration.
191—Oedipodinae of Utah (Technical).
192—Biennial Report of Director, 1923 and 1924.
193—Cache County Water Conservation District No. 1.
194—The Influence of Storage on the Composition of Flour (Technical).
195—Field Studies of Sugar-beet Nematode.
196—Fruit Tree Leaf Roller.
197—The Pear Leaf Blister Mite as an Apple Pest.
198—Report of Director (for 18-month Period from Jan. 1, 1925 to June 30, 1926).
199—Mutual Irrigation Companies in Utah.
200—Maintaining Potato Yields by Hill Selection.
201—Economic Insects in Some Streams of Northern Utah.
202—Some Observations on Winter Injury in Utah Peach Orchards.
203—Cattle Ranching in Utah.
204—Sheep Ranching in Utah.
205—The Beet Leaf Hopper in Utah.
206—Treehopper Injury in Utah Orchards.
207—The Physical Curd Character of Milk and Its Relation to the Digestibility and Food Value of Milk for Infants.
210—The Mineral Contents of Grains.
211—Silage Corn Varieties for Utah.
212—Studies on the Morphology of the Beet Leafhopper.
213—Food Habits of Utah Farm Families.
214—An Economic Survey of the "Dixie" Section, Washington County, Utah.
215—Cost Reduction in Dry-farming in Utah.
216—Notes on Miscellaneous Insects of Utah.