Symptoms of Nutritional Disorders in Sugar Beets[1]

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A knowledge of symptoms of nutritional disorders is another very useful tool which may be used in soil-fertility control. The more commonly grown agricultural crops, including sugar beets, are normally green in color. Any other color is abnormal and unless insects or diseases are the cause it is very likely that the condition is due to faulty nutrition. It is true that unfavorable weather conditions may accentuate nutrient deficiencies and thus intensify the symptoms of deficiency but it is not correct to say that such abnormal colors as yellow or purple are "simply due to the weather."

When nutrients are lacking, most plants sooner or later become yellow. One must decide which nutrient is lacking from the pattern of yellowing and from the location of the leaves which first turn yellow. Sometimes the pattern may not be exactly characteristic and sometimes two elements may be contributing to the abnormal appearance. At such times confusion may be avoided by making use of chemical tests on either the soil or certain portions of the green plants. The chemical tests are also very useful in differentiating between abnormal appearances caused by nutritional deficiences and those caused by insects or diseases.

Nitrogen Deficiency

Nitrogen exists in the soil largely as a constituent of organic matter. Through decomposition of the organic matter by soil organisms the nitrogen is changed into forms available to plants. The final product in the soil-nitrogen cycle is nitrate nitrogen. This is the form in which most plants prefer their nitrogen. Since the decomposition of the organic matter is dependent on the activity of living organisms, nitrogen availability in soil is influenced by temperature, moisture, and aeration.

This explains why sugar beets are often found starving for nitrogen on soils fairly well supplied with organic matter. This occurs during cold wet seasons, sometimes during periods of drought following a season of cold wet weather. The condition was strikingly illustrated in July and August of 1947 when beets on the Brookston soils of the Saginaw Valley and Thumb areas of Michigan were quite generally deficient in nitrogen. This was probably due largely to a lack of aeration caused by excessive compaction of the soil during the heavy spring rains.

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Figure 1.—Nitrogen deficiency causes very light-green to almost yellow leaves. The plant on the left was starved for nitrogen. Note the horizontal position of the leaves. The plant at the right received as ammonium nitrate all the nitrogen it needed.

Figure 2.—Sugar beets may obtain their nitrogen from decomposing alfalfa. In pot number 1 sugar beets were grown after corn which had followed alfalfa. In pot number 2 the sugar beets followed alfalfa directly. Notice the larger, greener, top growth. The lower leaves on the plants in pot number 2 were getting yellow when the picture was taken. The available nitrogen supply was evidently becoming exhausted. In pot number 6 the beets were grown after wheat, without a legume in the rotation.

Figure 4.—Sugar beets deficient in phosphorus grow slowly and are very dark green during the early part of the growing season. The leaves may or may not be fringed with red.

Figure 5.—In the later stages, phosphorus-deficient sugar beets become light green in color. The appearance at that time is suggestive of nitrogen deficiency. The green-tissue test may be necessary to avoid confusion.

As the soil nitrate supply becomes depleted the leaves become light green and eventually yellow as the deficiency becomes more serious. The loss of chlorophyl and the resultant yellowing occurs first on the older leaves and is uniform over the entire area of each leaf. This is an important point as in the yellowing caused by manganese deficiency, the veins and the leaf tissue close to the veins remain green. This gives the leaf a mottled appearance. Another characteristic of nitrogen deficiency is the direction in which the leaves grow out from the crown. Instead of standing erect as they do in a normal plant they grow out in a horizontal direction to give the beet the appearance of having been stepped on. This, together with the color difference, is illustrated by figure 1. An examination of figure 2 furnishes an opportunity to compare the appearance of beet leaves yellowed from three deficiencies—nitrogen, manganese, and potassium.

Where there is confusion between the three deficiencies, the green tissue test for nitrate nitrogen may be used to very good advantage. When the crop is growing rapidly, a *soil* test for nitrate is always low, as the plants take it up as fast as it is formed in the soil. Still there might be enough to satisfy the requirement of the plants. In other words, under those conditions, the soil test is not a true measure of the power of the soil to produce nitrate. A test of the green tissue, however, really shows whether or not the plants, at that particular time, are getting all they need.

Alfalfa as a green manure crop is a very good source of nitrogen for sugar beets. On tours of the sugar beet areas in early September it has been possible, usually, to tell from the color of the beet leaves the number of years that have elapsed since a field has produced alfalfa. Invariably the dark-green beets have been found in fields where the preceding crop was alfalfa or where but 1 year had elapsed since alfalfa was plowed under. Tissue tests on such fields have always indicated sufficiently high nitrate levels. Where the beets have showed distinct signs of nitrogen starvation, it has usually been found that the field had not grown alfalfa or clover for several years. An illustration of how alfalfa affects the appearance of sugar beets may be obtained from figure 3.

Phosphorus Deficiency

Phosphorus is held in the soil in a highly immobile condition. A portion is absorbed by the clay and held in an exchangeable form ready for use by the plant upon contact by the roots. Some is held as slowly available iron and aluminum phosphates and some as available but insoluble calcium and magnesium phosphates.

As a result of this fixed condition of the phosphorus, plants are most likely to starve for phosphorus while they are small, before the roots become well established, and during cold wet periods when the roots are not growing or growing slowly. At such times the nutrient absorbing root surfaces are not being formed fast enough to contact a supply of phosphorus sufficient for the needs of the growing portions of the plant.

A deficiency of phosphorus delays the emergence of sugar beet seedlings and makes them less resistant to disease. Once the plants have emerged they grow slowly and become stunted. The stunted plants have small *dark-green* leaves which, in extreme cases, are fringed with red, as shown in figure 4. If the red color is present, the symptom is very reliable. If the red color is not in evidence it is well to make a tissue test for phosphorus. A low phosphorus test confirms the suspicion. Such leaves always test high in nitrate. The test should be made on the petioles of the older leaves.

The unusually dark-green leaves are the result of an extremely high nitrate content. When growth is held back because of a lack of phosphorus the plant takes in nitrate in excess (luxury consumption). The small green leaves on phosphorus-deficient plants stand more erect than on normal plants, as shown in figure 10. This is in contrast to the horizontal position of the light-green leaves on the nitrogen-deficient plant shown in figure 1.

After about the middle of the growing season, if phosphorus deficiency continues to be serious, the beet leaves gradually lose their dark-green color and finally become very light-green or yellow as shown in figure 5. The older leaves die and the condition very closely resembles nitrogen deficiency. Such plants will, however, have a high content of nitrate so the test is very useful in avoiding a mistake. During the latter part of the growing season it is always desirable to use the nitrate test to distinguish between these two deficiencies.

Potassium Deficiency

Although the heavier soils, where sugar beets are most commonly grown, contain large quantities of potassium much of it is in mineral form and not readily available to plants. The potassium held by the clay and organic colloids, in the exchangeable form, and that continually being liberated in the decomposition of fresh organic matter furnishes most of that used by growing plants. Sugar beets do especially well on soils well supplied with organic matter. Perhaps the fact that they contain so much potassium, and so have need of a soil where the element is plentiful, is one of the reasons.

When the soil supply of available potassium becomes depleted, the oldest leaves are first affected. This is because of the translocation of potassium from the old to the new growing tissue. The leaves start turning yellow first at the tip and along the edges. Gradually the yellow area works toward the center of the leaf and the edge turns brown. Sometimes the chloratic area becomes yellowish gray rather than a distinct yellow as is characteristic of bean leaves yellowed by potassium starvation. The number 2 leaf shown in figure 2 was taken from a potassium-deficient sugar beet. Compare with it the leaves from nitrogen- and manganese-starved beets, shown in the same picture.

Tissue tests for potassium should be run on leaf petioles. In some cases it has been observed that plants showing slight-to-medium symptoms of potassium starvation test low-to-medium in potassium. In other words, plants with such symptoms do not always test blank. This probably means that for maximum growth, sugar beet leaf petioles should contain potassium sufficient for a high test.

Manganese Deficiency

The availability of manganese to growing plants depends, according to Sherman and Harmer, (2)[3] on the degree of oxidation of the manganese. Under alkaline conditions the oxidation-reduction equilibrium swings toward the manganic side and plants are unable to obtain manganese for normal growth.

Sugar beets are commonly grown in Michigan on neutral to alkaline soils. As a result, manganese deficiency is common. It is most severe on the soils of highest alkalinity, especially on highly alkaline sandy soils. The deficiency may appear in the plant at any time during the growing season and is first noticed as a mottling of the new growth. The green color gradually fades from the leaf tissue between the veins. The veins themselves and the area closely adjacent to the veins remain green for a considerable period after the rest of the leaf is yellow. The number 1 leaf shown in figure 2 is typical of beet leaves badly deficient in manganese. Sometimes the veins are much less distinct. In fact, it is occasionally difficult to distinguish the mottling. In such cases there is a possibility of confusion between manganese and nitrogen deficiency. Then one should resort to the use of the green-tissue test for nitrate nitrogen. This should be run on the leaf petiole. If the test is positive, it is safe to assume the yellowing to be due to something besides nitrogen deficiency. Whenever manganese deficiency is suspected it is always wise to determine the reaction of the soil. If the pH is above 6.8, manganese deficiency may be expected.

Boron Deficiency

Boron is not plentiful in Michigan soils. However, the total quantity of boron in a soil is of little importance. The important consideration is the state of availability. In neutral or alkaline soils, availability is slow and on such soils sugar beets develop normally only if boron is applied as a fertilizer.

Boron deficiency of sugar beets has for many years been termed "heart rot." It was so called long before it was realized that a lack of boron caused the disease. Investigators in Germany and France spent many years trying to isolate an organism responsible for the death of the heart tissue. Of course, they were not successful and in 1931 Brandenburg of Germany showed that the disease could be prevented by adding soluble boron to the soil. Heart rot was observed in Michigan by Kotila (1) in 1934.

[3]The numbers in parentheses refer to literature cited.

There are several rather specific and different symptoms of boron deficiency which may or may not all occur on the same plant. Some plants may have both top and root symptoms while some may have top symptoms only, others may have only root symptoms.

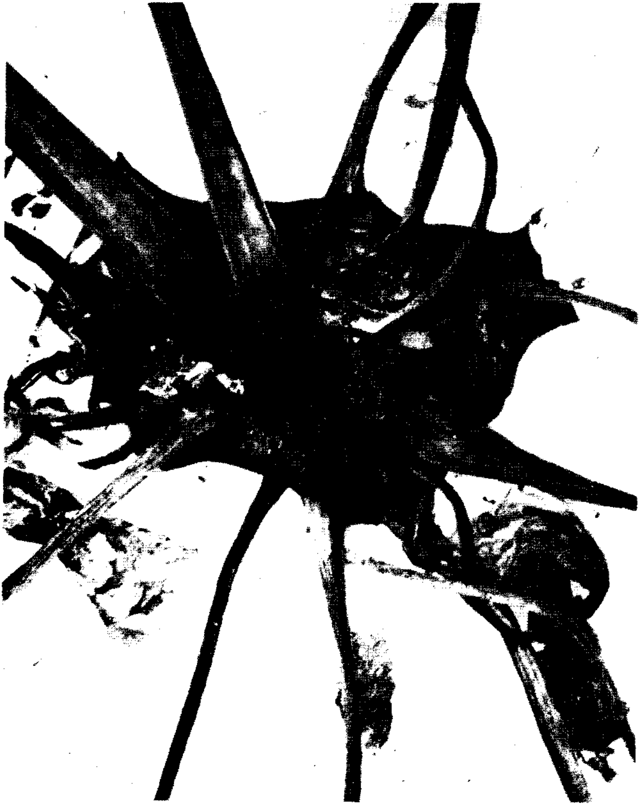

Figure 6.—Sugar beet deficient in boron. This plant illustrates the reason for calling the disorder "heart rot".

The most noticeable symptom is the dead heart illustrated by figure 6. This is first noticed during mid-summer, after the beet has attained considerable size. The leaves may all die. On severely affected fields the crop may be almost entirely defoliated by the end of the summer. Some beets actually die but most of them make new growth during the early fall months until new leaves, from around the edge of the crown, may almost cover the dead heart.

Perhaps the first symptoms of heart rot are cross-checked petioles and misshapen leaves, illustrated in figure 7. The leaves seem to grow unevenly on the two sides. This causes the petioles and midribs to twist and the leaf to develop only on one side. There is also a tendency, as shown in figure 8, for the development of a large number of small leaves, few of which ever reach normal size.

Boron-deficient beets also give one the impression of having been stepped on. They resemble nitrogen-deficient beets in this respect but differ from them in that the leaves are dark green rather than light green. After boron-deficient beet leaves start to disintegrate they turn yellow, brown, and black.

The roots of sugar beets affected by heart rot vary greatly in the extent to which they break down. In fact, some plants show by their leaves

Figure 7. Boron-deficient sugar beet showing the cross-checked petioles and twisted, misshapen leaves.

that a deficiency of boron exists while their roots appear perfectly normal. Usually, however, the root tissue turns black and disintegrates to various degrees. In some cases the whole crown breaks down while in others the disintegration is scattered throughout the beet. When the disintegrated areas break through the surface they appear as external cankers. A good idea of the appearance of boron-deficient sugar beet roots may be obtained from figure 9.

Figure 8.—Many sugar beets deficient in boron develop a large number of small abnormally shaped leaves. There seems to be a tendency for the plant to try to cover the injured heart area with leaves. In such cases the leaves remain small.

Sugar beets are so sensitive to a deficiency of boron that in Michigan it is recommended that borax be included in the fertilizer for beets on all soils, although it is only on the alkaline soils that heart rot has been found serious. When the fertilizer is placed in bands beside the seed or in contact with the seed, the rate of application need be only 7 to 10 pounds per acre. More than that quantity may be toxic when placed in direct contact with seed.

Sand Culture Experiments

Sand cultures have been used very advantageously in deficiency symptom studies. (3) In such experiments the importance of several other elements in the nutrition of the sugar beet has been demonstrated. Beets have been grown in glazed pots filled with quartz sand, with all nutrients mixed with the sand as one treatment, and with single elements omitted as other treatments. A fairly good idea of the technique involved may be gained by examining figure 10.

Figure 9.—Boron-deficient sugar beet roots. Notice the canker on the side of the whole beet, the blackened tissue in the left longitudinal section, and the dead hearts in the other two. The beets had attempted to cover the dead hearts with new growth. The three cross-sectional pieces were from beets with very bad cankers, places where the internal breakdown had broken through the epidermis.

Calcium Deficiency

A complete lack of calcium in a sugar beet soil is just as detrimental to the growth of sugar beets as is an absence of potassium. This was proved in the experiment represented by the cultures shown in figure 10. In that experiment the plants which did not receive calcium would have died while very small had not a small amount of calcium been applied. After the small addition was exhausted the plants gave evidence of the fact by the death of the newest leaves as shown in figure 11. Apparently a continuous supply of calcium is always necessary in the growth of this plant. Perhaps that is an important reason why sugar beets do not do well on acid soils.

Magnesium Deficiency

Magnesium deficiency in sugar beets has not been observed in the field but there is a possibility that under certain conditions such a deficiency may occur. More research work with this element may reveal such conditions.

In sand cultures the omission of magnesium from the nutrient solution has resulted in plants similar to those produced in cultures where potassium was omitted except that in the case of magnesium deficiency necrotic areas appear throughout the entire area of the leaf, rather than just around the edge. An idea of the pattern may be obtained from an examination of figure 12.

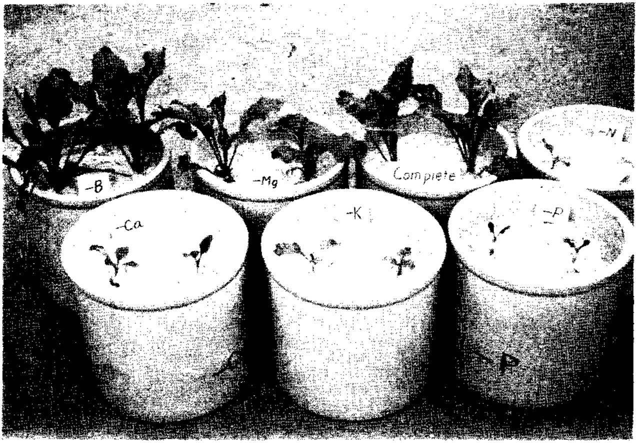

Figure 10.- Sand cultures have been found very useful in studying deficiency symptoms. In such experiments the control treatment has included all essential nutrients mixed with the sand, called the complete treatment. The other treatments have been formed by omitting single nutrients.

Iron Deficiency

In sand cultures a lack of iron has depressed sugar beet yields and resulted in a characteristic leaf chlorosis. The pattern is not unlike that displayed by other plants starving for iron—green veins on a very light-green to yellow background. This deficiency is also illustrated by figure 12.

Summary

Undernourished plants indicate by their appearance that they are obtaining an insufficient supply of nutrients. It is normal for sugar beet leaves to be dark green. Any other color is abnormal and unless insects or diseases are the cause it is very likely that the condition is due to faulty nutrition, and not simply to adverse weather conditions.

Nitrogen-deficient sugar beet leaves are uniformly light green in color and they spread out in a horizontal direction. In the early stages of growth, phosphorus-starved sugar beets produce small dark-green leaves which may or may not be fringed with red. During the latter part of the growing season the leaves turn uniformly yellow if the supply of phosphorus remains inadequate. Where potassium is deficient in the soil the leaves turn yellow at the tips and along the edges. Necrosis then works in from the edge of the leaf toward the center. Magnesium-deficiency symptoms resemble those of potassium but the chlorosis and necrosis appear in spots anywhere on the leaves, rather than first along the edges.

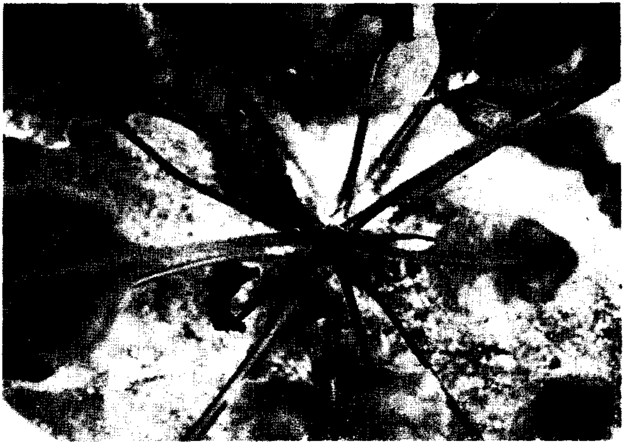

Figure 11.—Calcium-deficient sugar beet. Note the dead center leaves. Calcium deficiency shows up in the new growth.

Manganese deficiency shows up as a yellowing of the leaves with the veins and sometimes the tissue close to the veins remaining green. Iron deficiency closely resembles manganese deficiency.

A lack of boron in the soil causes heart rot of sugar beets. The heart tissue dies and the root gradually disintegrates. Leaves develop cross-checked petioles and twisted midribs, with development faster on one side of the leaf than on the other.

Calcium deficiency resembles boron deficiency in that the new center leaves are affected but the heart tissue does not disintegrate.

Figure 12.—A comparison of three deficiencies. Left, normal leaf. Next, magnesium deficiency. Note the necrotic areas throughout the leaf, also slight yellowing near the leaf margins. Third from left, iron deficiency. Veins very dark green and prominent against a yellow background. Right, manganese deficiency. Veins remain green but are less prominent than in the case of iron deficiency; gives leaf a mottled appearance.

Literature Cited

(1) KOTILA, J. E., AND COONS, G. H.
1935. Boron deficiency disease of beets. Facts About Sugar. 30: 373-376.

(2) SHERMAN, G. DONALD, AND HARMER, PAUL M.
1942. The manganous-manganic equilibrium of soils. Soil Sci. Soc. of America Proceedings. 7: 398-405.

(3) WEIDEMANN, A. G., AND COOK, R. L.
1946. A greenhouse study of deficiency symptoms in sugar beets, with details for the preparation of balanced nutrient solutions. Soil Sci. Soc. of America Proceedings. 11: 361-368.