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MANGANESE STATUS AND NEEDS *of the Southern Region*

BY THE CLOSE of the last century research workers had indications that manganese was benefical for plant growth. But, not until the early years of this century could chemicals be purified sufficiently to prove plants' essential need for manganese. This was established in 1914 with corn, and a few years later it was proven to be essential for growth of a number of other plants.

Manganese in Plants

Manganese is an integral part of at least one enzyme system, and it serves as "activator" for others. In this role, plants can use manganese over and over again. Yet, a lack of manganese can limit, or even halt normal plant growth.

An "activated" enzyme must be present for most metabolic reactions before they will proceed rapidly enough for plant growth. Often an enzyme alone will not speed up a reaction, but the enzyme plus manganese as an "activator" will. Sometimes other elements, such as magnesium, can substitute for manganese in this activating process, but aren't as effective as manganese in most cases.

Manganese also plays a direct role in photosynthesis. When it is deficient, photosynthetic activity is depressed. It is now thought that this direct effect of manganese is associated with one particular phase of photosynthesis, that of oxygen evolution.

There are indirect roles of manganese in photosynthesis, too. Given sufficient time under manganese deficient conditions, a plant will have less chlorophyll in its leaves. This condition indicates a role of manganese in either chlorophyll synthesis or breakdown. A loss of chlorophyll—often called chlorosis—is the most common symptom of manganese deficiency.

Because plants are able to reuse manganese, they require very small amounts. Table 1 shows representative quantities of manganese in several plants. These quantities, however, are generally much larger than for other micronutrients. For example, many crops contain eight to 10 times as much manganese as copper.

Concentration of manganese in plant material will vary with many factors—different plants, soils, etc. Generally, the concentration is in the range of 100 to 300 parts per million.

FIGURE 1.
CROPS REPORTED HAVING SHOWN MANGANESE DEFICIENCY OR TOXICITY IN THE SOUTHERN REGION.
CASES FOR TOXICITY ARE IN PARENTHESES.

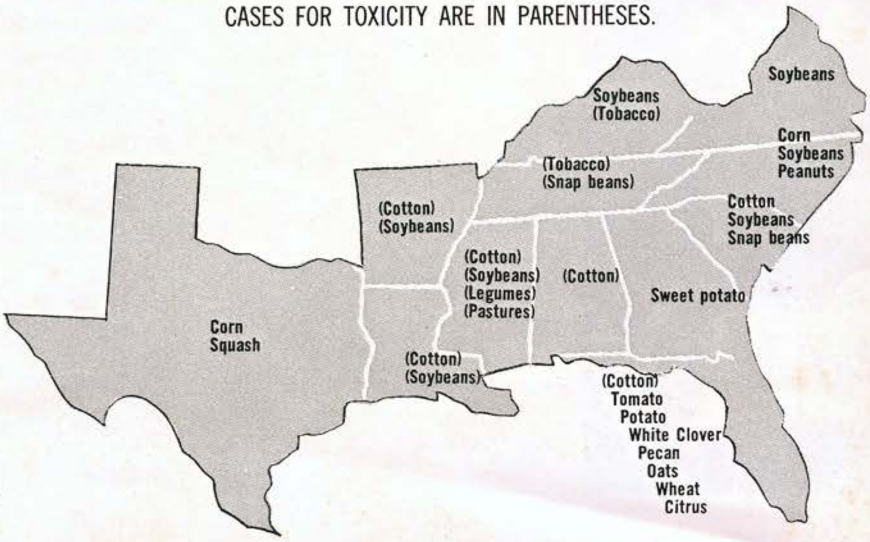

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TABLE 1.

MANGANESE IN CROPS

		Acre Yield	Lb. Manganese/acre
Corn	— grain	150 bu.	0.09
	stover	4.5 tons	1.50
Wheat	— grain	40 bu.	0.09
	straw	1.5 tons	0.16
Rice	— rough	80 bu.	0.08
	straw	2.5 tons	1.58
Alfalfa		4 tons	0.44
Cotton	— seed and lint	1500	0.11
Peanuts	— nuts	2500 lb.	0.01
Sugar beets	— roots	15 tons	0.75
Tobacco	— leaves	2000 lb.	0.55

Normal barley plants on left; manganese deficient plants on right.

Manganese Problems

Reported instances of manganese deficiency in the South are shown in Figure 1. Fourteen different crops have been reported as showing manganese deficiency.

In very acid soils, however, manganese becomes so soluble or available that it can be toxic. Six crops have been reported as having this trouble.

Since there can be either too little—which more frequently is the problem with manganese—or too much manganese for good plant growth, it is important to understand some of the factors affecting manganese availability in soils.

Factors Affecting Availability

1. Total Soil Manganese. Soils vary in total manganese content from less than 300 to greater than 6000 pounds per acre. However, only a small portion of this is actually available to plants. The availability of this small portion generally is more dependent on other soil and environmental factors than on the total amount in the soil. There are a few situations, however, in which a deficiency of manganese can be related to the total content in the soil. Such situations are almost always related to organic soils since they usually contain much less total manganese than do mineral soils.

2. Soil Acidity. The most important soil factor in determining manganese availability is the degree of soil acidity. Most soils of the South, as they occur naturally, are moderately or strongly acid with a pH range of 4 to 5.5.

The effect of raising the pH (decreasing acidity) on the availability of manganese is striking. At a pH of 4 it is extremely soluble or available. Manganese toxicity normally occurs in the pH range of 4 to 5. If such soils are limed to a pH of at least 5.5, availability is decreased and toxicity usually eliminated.

When certain soils are limed to a pH of greater than 6, manganese deficiency may occur. Why these soils exhibit manganese deficiency with liming, while others do not, is not fully understood.

Effects of different pH levels on

manganese concentrations in soybean leaves are illustrated in Figure 2. It shows that soybeans had much higher manganese concentrations at pH 5.4 than at 6.5, and that increasing amounts of soil manganese were more effective in increasing plant manganese content at pH 5.4 than at 6.5.

The reason manganese becomes less available as the soil reaction is changed from strongly acid to near neutrality is thought to be due primarily to formation of manganese oxides. There are a number of these oxides and as the pH is raised the more insoluble ones are formed. Bacteria also will make manganese less available and bacterial activity is generally increased as the pH is raised.

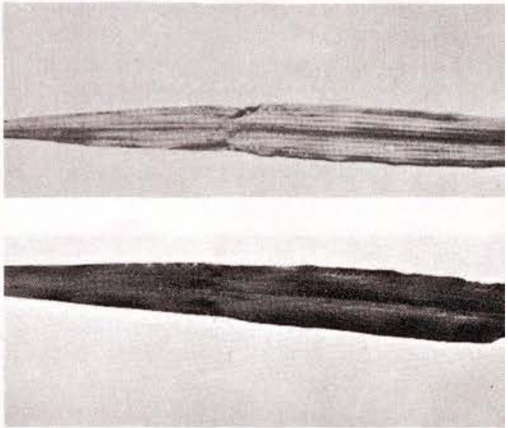
3. Soil Organic Matter. Soil organic matter affects manganese availability in two ways. First, organic matter will complex or hold manganese in a relatively unavailable form. The availability of complexed manganese also depends upon the soil reaction since it is held more tightly as the pH is increased. Second, the changing of manganese oxides to a more available form through chemical reduction can be brought about by organic matter.

4. Soil Moisture. Another way in which manganese may be made more available is by waterlogging the soil. This condition also results in a chemical reduction of the manganese oxides to more available forms. If prolonged, this condition could lead to manganese toxicity by causing a low-oxygen supply in the soil.

5. Environmental Factors. Certain environmental factors affect manganese uptake by plant roots. It has been noted, for instance, that manganese uptake is decreased as light intensity is decreased. Also, manganese becomes less available as the temperature is decreased.

Manganese is less available if soil moisture content is maintained at an optimum level for plant growth rather than allowed to dry occasionally. Thus, manganese deficiency is likely to be most severe under cool, moist, springtime conditions.

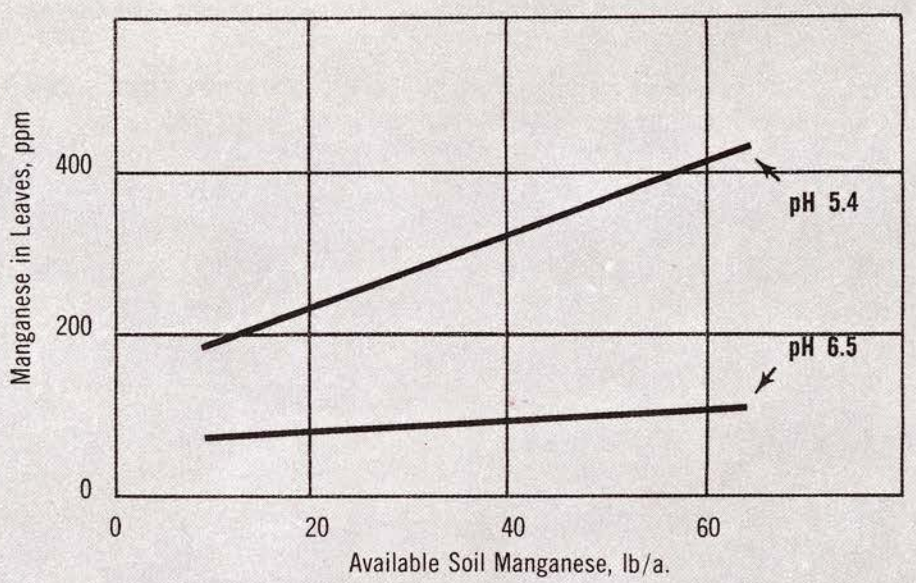
"Crinkle leaf of cotton—a symptom of manganese toxicity.



Manganese deficient barley leaf (upper) showing chlorotic areas between veins. Lower leaf is normal.

FIGURE 2.

MANGANESE CONCENTRATION IN SOYBEAN LEAVES AT DIFFERENT SOIL pH AND MANGANESE LEVELS.



Deficiency Symptoms

A chlorotic pattern and stunting of growth are usually the first visual symptoms of deficiency. As the deficiency becomes more severe, necrotic (dead) spots appear in the chlorotic areas. Leaf tissue between the veins turns yellow while veins remain green.

Soybeans, snap beans, peanuts, tomatoes, potatoes and citrus may have a mottled (irregularly colored area) appearance before the striking interveinal chlorosis appears. In cereals, the interveinal pattern first produces chlorotic stripes since the veins are parallel. As necrotic spots develop the leaf may weaken and break over. Manganese deficiency in oats has long been called "gray speck" or "gray stripe."

The chlorotic condition shown by manganese deficient cotton is usually not as extreme as that shown by crops such as beans. Instead of becoming bright yellow between the veins, cotton often becomes yellowish gray or reddish gray. Plants often remain in the vegetative stage and fail to set fruit.

White clover appears to be an exception in that it does not develop a chlorotic pattern when short of manganese. Instead, its leaves have a bronze cast, and are smaller than normal.

Toxicity Symptoms

General symptoms of manganese toxicity are deformed leaves, chlorosis, necrotic spots, stunting and reduced yields. In cotton, the bolls may be affected and yields reduced before leaves show visual symptoms. The symptom in cotton is appropriately called "crinkle leaf" because leaves crinkle or pucker at the edges which cup downward. The edges may become quite ragged. Such leaves are thicker and more brittle than normal. Affected leaves are often partially chlorotic or sort of yellowish green. Later, necrotic spots may appear either between or along the veins.

Manganese toxicity in soybeans produces leaf deformation similar to that in cotton. However, soybean leaves become much more chlorotic than cotton leaves.

In tobacco, the chlorosis due to excess manganese tends to be more interveinal than is the case with cotton. The larger tobacco leaf veins may remain quite green.

Correcting Deficiency and Toxicity

Many of the abnormal manganese conditions are associated with extremes in soil reaction. Liming is recommended to correct a toxic condition. As explained previously, liming will reduce the solubility of soil manganese. Soils should be limed to a pH of at least 5.5 to correct manganese toxicity.

It is very difficult to predict accurately with soil tests the occurrence of a manganese deficiency. Soil tests for manganese thus far have been most useful in confirming deficiency symptoms observed visually. In North Carolina, manganese determinations are made on soil samples if requested. Suggestions for application are based on the quantity of available soil manganese, and on the pH level.

Several forms of manganese may be applied to correct a deficiency. The two most common—manganese sulfate and manganous oxide—may be applied to the soil or to the plants. Commercial manganese sulfate ($MnSO_4$) is 20-25 per cent Mn, and manganous oxide (MnO) is usually about 50 per cent Mn. Another form, which is used primarily as a spray, is chelated manganese. Manganese is also available in frits for soil application.

Recommendations in the southern region to correct manganese deficiency are usually in terms of manganese sulfate. The average recommended soil application is 25 pounds of manganese sulfate per acre. One state recommends as much as 50 pounds if the deficiency is severe. Manganese sulfate should be banded with fertilizer for greatest efficiency.

As most of the applied manganese is "fixed" by the soil, applications are necessary each year where a deficiency occurs. In some soils, successive applications build up the soil manganese level to where there is no longer a deficiency.

Manganese sulfate is also recommended for spraying or dusting. Spraying appears to be slightly more effective than dusting, and about three times as effective as a soil application of this salt. Therefore, the average rate of manganese sulfate recommended for spraying is about one-third that suggested for soil application.

Manganese deficiency conditions which have been induced by excessive amounts of lime can be corrected by adjusting the soil reaction. Sulfur can be added for this purpose. The application should be based on a soil test. □

Manganese deficient soybeans showing light colored tissue between leaf veins that tend to remain green.