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IRON

Robert Baudendistel
Department of Floriculture
Cornell University

Iron has long been recognized as an essential element for plant growth. Although it is not required by plants in such large quantities as nitrogen or potassium, it is essential for normal growth. Iron is present in almost all soils, however, only a small amount of it is available for plant growth. The availability of the iron is dependent on a number of different factors which will be reviewed in this article.

In the soil, iron is found in two separate valence states:

1) Fe^{++} ferrous iron or the reduced form
2) Fe^{+++} ferric iron or the oxidized form

Plants, however, are only able to use iron in the reduced or ferrous form. If all of the soluble or exchangeable iron in the soil is in the ferric or oxidized form, chlorosis will probably result.

The lack of iron in a plant is exhibited by chlorosis. Iron chlorosis first appears near the tips of shoots which are rapidly growing and developing. In the early stages, the areas between the veins are light green. These areas later become yellow and finally white or cream colored as chlorosis becomes more severe, followed by, many times a severe burning of the chlorotic leaves.

Iron chlorosis may be due to:

I) A complete lack or unavailability of iron in the soil—this type of chlorosis may be brought about by:

a) too high a pH,
b) excessive phosphorus, or
c) an excess of heavy metals.

II) A root injury which prevents the uptake of iron. This injury may be the result of any one or a combination of the following:

a) high soluble salts,
b) root diseases,
c) nematodes, or
d) symphilids.

III) A failure of the roots to function properly, which usually is brought about by:

a) low soil temperature, or
b) lack of proper soil aeration.

When chlorosis appears, each of the above factors must be checked to determine which one is the causative factor. The grower must make sure that he treats the real cause of chlorosis and not merely the symptoms, since applications of iron compounds have no effect on controlling the action of nematodes, even though they might correct the chlorosis temporarily.

Since these various environmental factors govern the availability of iron, the function of each factor must be thoroughly understood before the chlorosis can be prevented or "cured." Therefore, each factor concerned with the problem of iron chlorosis will be discussed with regards to its particular effect on the availability and uptake of iron, and what measures can be taken to help prevent chlorosis.

Soil Acidity (soil pH)

The solubility of iron in the soil is largely governed by the pH of the soil. It becomes more soluble as the soil becomes more acid, and less soluble in alkaline soils. In fact, in soils having a pH greater than 7, the exchangeable or available iron may be so low that plant roots are unable to absorb enough for healthy growth with the result that the leaves become chlorotic.

Ferrous salts are characterized by being relatively stable in the presence of air in an acid medium, but are readily oxidized to the ferric state by atmospheric oxygen in neutral or alkaline media and ferric iron is not used by the plant.

Presented in Figure 1 is a graph showing the relationship between the amount of iron dissolved in the soil and the soil pH (as extracted with Ammonium Acetate

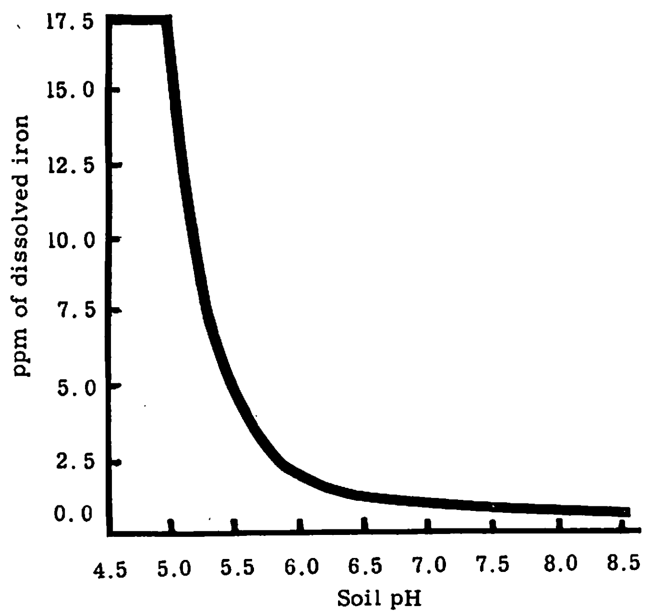

FIGURE 1. The relationship between soil pH and amount of iron dissolved in the soil (as extracted with 1 N Ammonium Acetate solution of pH 4.8). (from Olson)

(Continued on page 2)

IRON . . . *(continued from page 1)*
solution of pH 4.8). Evident from the figure is the fact that the amount of soluble iron decreases rapidly above pH 5.5. Another fact not clearly evident from the figure is that below pH 4.5, toxicities due to excess iron may be encountered in the soil. This condition is usually corrected by applying basic fertilizers and raising the soil pH. However, care must be used in the amount applied, since too much basic fertilizer might neutralize the soil with the result that ferrous ions would be converted into inert ferric oxides and hydroxides which are unavailable for plant growth. Thus to insure proper availability of iron for the growth of plants, the soil pH should remain within the range of 4.5 to 6.5 for most plants, and below pH 5.0 for acid loving plants (azaleas, gardenias, etc.).

Phosphorus

At high pH levels, iron is rendered insoluble by combining with precipitated calcium phosphate in the soil. Excess lime has a similar effect. Below pH 4.5, iron is abundant and has the capacity to fix phosphorus. Figure 2 displays this relationship graphically. Thus, as the con-

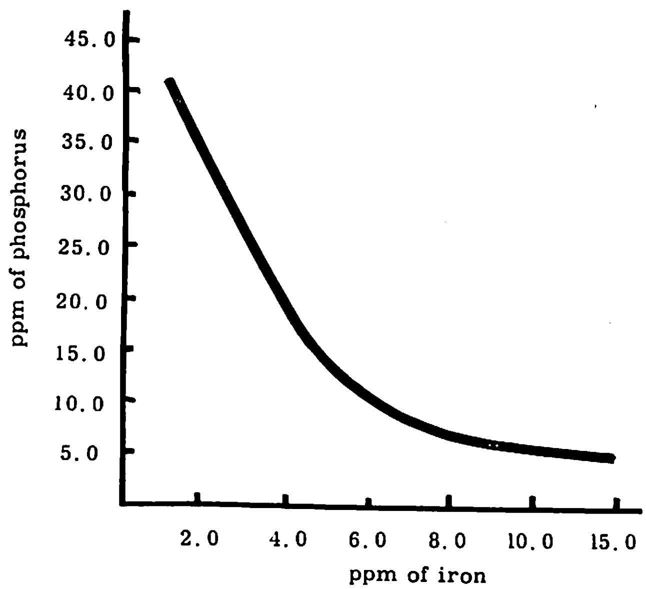

FIGURE 2. The relationship between soil test values for iron and phosphorus.

centration of phosphorus in the soil increases, the concentration of iron decreases. The opposite is also true. To combat this condition soil amendments, such as Ammonium Sulfate or elemental Sulfur, are used to increase the acidity of the soil with the result that unavailable forms of iron are made available. Liberal applications of non-decomposable organic matter (peat moss) also increase the availability of the iron in the soil.

Heavy Metals

An excess of heavy metals, such as manganese, zinc, nickel or copper, have been reported to cause iron chlorosis. Accumulation of these same heavy metals in the plant, especially copper, also has been shown to cause iron chlorosis. It has been found in Hawaii where the soils have a high manganese content, that the soil does not supply the plants with sufficient iron for normal growth. This condition is effectively corrected by applications of various iron compounds, either sprayed on the leaves, or added to the soil.

High Soluble Salts

Sometimes, iron chlorosis may be the result of high soluble salts in the soil. In this case, high soluble salts prevent the uptake of water and nutrients from the soil. The water and nutrients move out of the root cells into the more concentrated soil solution, causing plasmolysis or collapse of the root cells. This injury to the roots, if not corrected immediately, will eventually cause death of the roots, however, in the beginning stages will cause iron chlorosis. To protect against this injury, growers should have their soil tested frequently. If a soluble salts reading of 200 mohs or greater shows up (1:2 mixture), the soil should be leached with large volumes of water.

Diseases

Any disease which destroys roots and root hairs may indirectly cause iron chlorosis, due to a lack of absorption of iron. Among the root rot diseases which might be responsible are Rhizoctonia, Pythium, Fusarium, and Thielaviopsis. The best method of control for all of these organisms is steam sterilization.

Nematodes

Both root-attacking and root-knot nematodes have been found at various times to be the cause of iron chlorosis. Root-knot infested plants, under careful examination of the roots, will display galls, whereas, no galls are formed by the root-attacking type. Steam sterilization on raised benches gives the best control.

Symphilids

Symphilids, or garden centipedes, chew off root hairs causing stunting and sometimes chlorosis of the plants. One application of Lindane has been shown to be effective in controlling them for periods up to two years. Steam sterilization also gives good control on raised benches.

Soil Temperature

Roots of various plants may fail to function properly at low soil temperatures with the result that the leaves become chlorotic, as is the case with gardenias. Soil temperatures, lower than optimum, are responsible for the following reasons:

a) decrease the solubility of nutrients in the soil,
b) reduce the respiration of the roots, thus slowing down the growth of both roots and root hairs, and
c) decrease the absorption of water and nutrients.

Thus these factors, brought about by improper soil temperatures, may also be responsible for iron chlorosis. Growers should attempt to keep their soil and air temperatures above the minimum.

Soil Aeration

Plant roots do not function properly when the amount of oxygen in the soil is low. Roots require sufficient oxygen to carry on the process of respiration, which in turn governs both root growth and the absorption of nutrients. Thus, when oxygen is deficient in the soil, chlorosis may result due to a decrease in the absorption of iron even though iron may be abundant in the soil.

Furthermore, under water-logged or submerged soil conditions which may persist due to poor drainage, iron is rapidly reduced because of the lack of oxygen and its concentration may reach a toxic level. Soil compaction, or

(Continued on page 3)

sesses its characteristic properties, and is so strongly held in soluble form that it can not enter a chemical reaction to form such compounds as iron phosphates or hydroxides. Also, chelated iron is not subject to exchange with other metallic irons, is not influenced by the acid or alkaline reaction of the soil, and has the merit of being effective in very small amounts and of producing lasting results. Because it remains in solution rather than in a dissociated form, the iron is readily absorbed by plants. The chelating agent itself is also not decomposed by the soil microorganisms as are certain other organic acids.

Various chelating agents have been used to correct iron chlorosis. They are Ethylenediaminetetra-acetic acid (EDTA), Hydroxyethylethylene diaminetri-acetic acid (HEEDTA), Diethylenetriaminepenta-acetic acid (DTPA), Cylcohexanediaminetetra-acetic acid (CDTA), and Aromatic polyamino carboxylic acid (APCA). Fe-CDTA is the most effective of these chelates in providing iron at pH 7, followed in decreasing order by APCA, DTPA, HEEDTA, and EDTA.

Both Fe-EDTA and Fe-HEEDTA have been shown to be good sources of iron when applied to acid soils, but were found to be ineffective on alkaline calcareous soils.

The most satisfactory chelate tested on alkaline calcareous soils has been Fe-APCA, followed by Fe-DTPA. Even though Fe-APCA has been found to be the most effective and the least toxic of all the chelates tested, its cost of production makes it undesirable for commercial use. However, many other new chelates, equipped with many characteristics similar to Fe-APCA and less expensive to produce, are being tested at the present time on both acid and alkaline soils.

It must be understood, however, that iron chelates are not "cure alls." They can be used effectively when chlorosis is due to a complete lack or unavailability of iron, but like other inorganic forms of iron, they are not effective in treating the real cause, but only the symptoms, when chlorosis is due to either a root injury or the improper functioning of the roots.