Nutrient Profile: Iron

By Dr. Doug Soldat, *Department of Soil Science, University of Wisconsin-Madison*

Of all the nutrients in the soil, iron is found in the greatest abundance. In fact, soils are largely made of iron-containing compounds. Think of Wisconsin's eastern red clays and the red earth in the southern US. The red color in those soils comes from iron oxide - more commonly known as rust. Iron is present in the soil because it is not very soluble and has persisted despite tens of thousands of years of rainfall and leaching. Therefore, it should come as little surprise to learn that iron is found in miniscule quantities in the soil solution, which is where the plants directly obtain nutrients. Even though total soil iron content is typically high, the *available* iron content may be very low, and iron deficiency symptoms can appear. Luckily, plants require only small amounts of iron to grow properly and actual iron deficiencies in turfgrass are extremely rare. This is not true for many other ornamental and native plants that cannot thrive or even live on high pH soils because of iron deficiency problems.

Iron is also one of the most complex nutrients in soils and plants. Researchers have found that the total amount of iron in the plant is not necessarily related to whether or not an iron deficiency appears. For example, you could find two of the same species of plant, both with 150 ppm Fe in the tissue and only one of the plants might show severe iron deficiency problems, while the other would be completely healthy. This is called the iron paradox and is a current topic of several research studies across the nation. Soil testing for Iron is not very simple either, as extractable iron in the soil is not well correlated with the iron in the plant. Some (like me) wonder about the sanity of using a soil test to predict tissue concentrations, if tissue concentrations are already known to be misleading. To summarize, there are known knowns about iron, and there are known unknowns. We will stick to the known knowns for the rest of the article (my apologies to the former Defense Secretary).

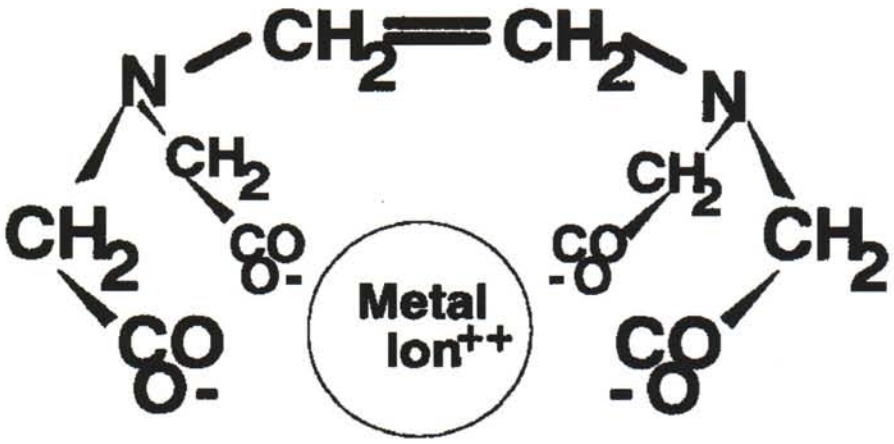

Figure 1. A conceptual representation of the chelation process, where a large organic molecule (in this case EDTA) binds with a metal ion like iron (Fe3+) like a hand gripping a ball. Notice how the negatively charged "fingers" of the EDTA molecule surround the positively charged, smaller metal ion. Look on your soda can, chances are EDTA was added to remove complex with the metal from the can to remove the metallic taste that would otherwise exist.

Foliar or Soil Application?

Iron availability is very sensitive to soil pH, and iron becomes less available as soil pH increases. Therefore, most iron deficiencies are seen in calcareous (high pH) soils, especially calcareous sands, which have very low total iron, compared with mineral soils to begin with. Because soil pH adjustment is impractical for large areas, periodic iron fertilizer applications are the solution to increasing iron availability. In the turf industry, iron is applied predominantly by foliar sprays. Soil applications are rare, or incidental (as when applying Milorganite, or another iron-rich material). There are many iron products available, and the two most important factors related to efficacy of the application are the form of iron (chelated or not) and the type of adjuvant used in the formulation.

Iron Chelation

Chelate (pronounced KEY-late), is derived from the Greek word for claw. This turns out to be a very descriptive name, because chelating molecules look similar to a hand closing in on another smaller atom or molecule, like iron (see Figure 1). Several natural and synthetic chelating (KEY-lay-ting) agents exist. These agents "grab" iron and other metals and keep them in the soil solution at much higher concentrations than would normally occur if the chelating agents were absent. Natural chelating agents are formed when soil organic matter decomposes

and grasses secrete their own iron-specific chelating agents called phytosiderophores into the root zone. Sometimes these natural chelating agents are insufficient for increasing the iron solubility to achieve optimum growth or plant health, and iron fertilization is required. Chelated forms of iron are recommended for soil and foliar applications of iron. This is because (as mentioned earlier) iron is very insoluble in the soil, and chelating agents can substantially increase the solubility of iron for a few weeks. If using a soil-based application, the most effective chelating agents in high-pH are EDDHA and DTPA. EDTA and glucoheptonate are common chelating agents that will not be effective in high pH soils.

Iron can also form insoluble compounds on the leaf surface. The degree of solubility is related to the chemistry of the spray tank solution. Because the tank mixtures for golf turf management tend to be complex, chelated sources of iron are probably a wise decision. If you add Fe-EDTA or Fe-glucoheptonate to a spray tank filled with hard water (pH=8.2, high in calcium), those chelating agents will rapidly drop the iron and complex with the calcium in the water. For this situation, an iron fertilizer containing EDDHA or DTPA would be a better choice. *In summary, know the pH of your soil and spray solution and soil to choose a product with a chelating agent that is effective with iron at that pH.*

Figure 2. The typical patchy, mottled look of Kentucky bluegrass suffering from iron deficiency.

Photo Credit: Dennis Robinson

Figure 3. Close up picture of creeping bentgrass blades with no iron applied.

Photo credit: Wayne Kussow, Todd Fregien

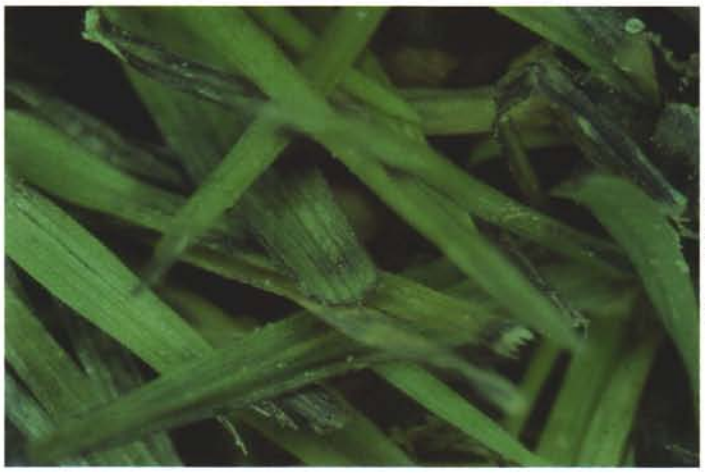

Figure 4. Close-up picture of creeping bentgrass blades following iron application.

Photo credit: Wayne Kussow, Todd Fregien

Breaking the Barrier

To penetrate the plant's waxy leaf surface, a chemical must be relatively small and preferably non-charged. (This is why urea is a good candidate for foliar uptake). Large molecules have trouble working their way through the tiny pores and cracks of the leaf, and charged molecules can be bound or repelled by the positively charged surfaces that line the pores in the plant. Most chelating agents meet the requirement of being relatively small and uncharged. The other important factor for foliar uptake is a low surface tension of the spray solution.

Adjuvants (or surfactants) are substances added to a product to decrease the surface tension of the spray solution and increase the foliar uptake of the active ingredient. A low surface tension allows the spray solution to spread out and cover more of the plant surface. More coverage by the spray solution increases the chance for penetration. There is a very large industry built around the research and development of surfactants for improving the efficiency of fertilizers and pesticides, attesting to the importance of these additives.

A True Deficiency or Aesthetic Response?

Insufficient Fe is not very common, but can occur in specific situations like high pH soils, or when nutrient uptake (including iron) is limited by low or excessive temperatures. The primary visual symptom of iron deficiency is a general yellowing or chlorosis of newer leaves. When viewed from afar, this yellowing, or chlorosis, tends to show up in a mottled or patchy pattern, unlike chlorosis due to N deficiency, which tends to be fairly uniform in nature (see Figure 2). Also, nitrogen deficiencies show up in older leaves first, as the plant is able to move N from older tissue to newer tissue. Because of its mottled appearance, iron deficiency is often mistaken for a water or drainage issue.

Probably less than 1% of all iron applications are made to turf truly deficient in iron. The other 99% are meant to enhance the color of the turf, or to get by with less N without sacrificing color. When the iron is intended only as "paint," chelation of the iron source becomes less important because precipitation of iron on the surface of the leaf will provide the desired greening or darkening effect.

The darkening effect is shown clearly in the two classic images taken by Dr. Wayne Kussow and former student Todd Fregien (Figures 3 and 4). When viewed up close, the foliar iron application left dark spots on the leaves. When viewed from a distance, the grass would appear a darker shade of green. This temporary staining disappears as the grass grows and the leaves are mowed off, usually lasting no longer than 10-14 days. Try spraying different rates of your foliar iron product to identify the rate that gives the best darkening color without turning the turf entirely black or brown (which is very possible). The optimum rate will not always be the rate suggested on the label.

In summary, iron is a complex nutrient in the soil, plant, and in the spray solution. If you are dealing with a true iron deficiency, consider relatively high rates of chelated iron to the soil and to the plant tissue. Most iron chelating agents are effective for low pH soils and spray solutions, but only a few (EDDHA and DPTA) have been shown to be effective in high pH soils and spray solutions. There is little doubt that iron applications can have beneficial aesthetic effects on turfgrass color when applied frequently by foliar application. However, the darker green color associated with iron-treated plants is not indicative of better physiological plant health. Frequent foliar applications of iron may be one solution for dealing with cuts in fertilizer budgets due to high fertilizer prices.