A3554

Understanding Plant Nutrients

Soil and Applied Iron

E.E. Schulte

Iron (Fe) is the fourth most-abundant element on earth, mostly in the form of ferromagnesium silicates. Soils typically contain 1–5% total iron, or 20,000–100,000 lb/a in the plow layer. Most of the iron in soil is found in silicate minerals or iron oxides and hydroxides, forms that are not readily available for plant use.

The iron oxides and hydroxides in soil are responsible for its reddish and yellowish colors. The red soils of eastern Wisconsin owe their color to iron oxide or hydroxide coatings on soil clay minerals. Iron is also indirectly responsible for much of the green color of growing plants, because of its role in the production of chlorophyll.

IRON REACTIONS IN SOILS

Iron in soil exists in ferrous (Fe^{++}) and ferric (Fe^{+++}) forms. Soil pH and the aeration status of the soil determine which form predominates. Ferric iron compounds have low solubility in the soil solution, and conditions that favor formation of these compounds decrease iron availability. Soil pH, soil aeration, reactions with organic matter, and plant adaptations influence iron availability.

Soil pH

The concentration of iron in the soil solution decreases sharply as the soil pH increases, with a minimum around pH 7.4–8.5. It is in this range that most cases of iron deficiency occur. While this is not widespread in Wisconsin, it can occur in calcareous soils.

Aeration

Poor soil aeration, or reduced oxygen level, is caused by flooding or compaction. It can increase or decrease iron availability depending on other soil conditions. Iron deficiencies occur most frequently in cool, wet soils early in the growing season, when microbial activity and root growth are limited. As the soil warms, microbial activity and root proliferation increase, allowing plants to absorb more iron. If microbial activity is sufficient to decrease the oxygen supply in acid soils, some ferric iron oxides and hydroxides will be transformed to more soluble ferrous forms. On the other hand, in alkaline soils rapid microbial respiration may produce sufficient carbon dioxide to react with water to form bicarbonate ions. Plant-absorbed bicarbonate ions immobilize iron within plants, resulting in deficiency.

Organic Matter

Organic matter improves iron availability by combining with iron, thereby reducing chemical fixation or precipitation of iron as ferric hydroxide. This reduction in fixation and precipitation results in higher concentrations of iron remaining in the soil solution, available for root absorption. Organic matter can also affect iron availability by acting as an energy source for microorganisms that use up oxygen under waterlogged conditions. When microorganisms decompose organic matter, iron previously tied up in organic compounds is released in forms available for plant uptake. Finally, many organic materials can also be sources of iron. Livestock manure contains 0.5–5.0 lb/ton of iron, depending on the manure source.

Plant Adaptations

Some plants cope with low iron availability in soil by excreting hydrogen ions (H^+) from roots, which lowers the pH at the root interface and increases the solubility of iron from iron hydroxides. Other plants excrete organic compounds that reduce ferric iron to the more soluble ferrous forms. Alfalfa, corn, and small grains are tolerant of low iron availability; most fruits and some ornamentals are sensitive to low iron availability.

FERTILIZER SOURCES OF IRON

Iron deficiency is difficult to correct because of the rapid transformation of iron contained in fertilizer to unavailable forms in soil. (See Table 1 for a list of several fertilizer sources of iron.) Iron chelates (iron in association with an organic ligand) applied to the soil have been successful in some cases. However, not all chelates remain stable over a wide range of soil pH, and the presence of other elements such as calcium influences different chelates to different degrees. Iron EDDHA maintains iron in a soluble form from pH 4.0 to 9.0 and is a good choice for use on calcareous soils. Iron DTPA is selective for iron up to pH 7.5. The

Table 1. Fertilizer sources of iron.

SOURCE	FORMULA	PERCENT IRON	METHOD OF APPLICATION
Chelates:	FeDTPA	10	Soil, foliar
	FeEDTA	9–12	Soil, foliar
	FeEDDHA	6	Soil, foliar
Ferrous ammonium sulfate	$(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$	14	Foliar
Ferrous sulfate	$FeSO_4 \cdot 7H_2O$	20	Foliar

EDTA chelate is least effective and will only remain stable up to pH 6.3, where iron deficiencies normally do not exist. The chelates should be applied to the soil before or at planting at the rates suggested by the manufacturer, usually about 0.5–2.0 lb/a of iron.

Foliar applications require only 0.10–0.15 lb/a of iron, but several applications may be necessary to correct severe deficiency. Ferrous sulfate and ferrous ammonium sulfate are used as foliar sprays. Typically, a 2–3% solution of either material is applied at a rate of 20 gal/a. Ferrous sulfate has given some success as a soil application to alleviate iron deficiency in turf. The limited soil contact that occurs with foliar applications reduces fixation, and its acidifying effect on soil improves uptake.

For ornamentals, shrubs, and trees, local acidification of calcareous soils is sometimes effective in correcting iron deficiency. Sulfur bacteria in the soil oxidize elemental sulfur to sulfuric acid; the sulfuric acid dissolves enough iron oxide to supply the plant with iron. Pour elemental sulfur into holes made a foot deep with a soil probe and spaced about 2 ft apart under the drip line. For a more immediate response, use battery acid (sulfuric acid) in a similar manner.

DIAGNOSTIC TECHNIQUES

Deficiency Symptoms

Iron is immobile in plants. Therefore, deficiency symptoms appear first on the youngest leaves. Plants need iron to produce chlorophyll. Lack of iron results in yellowing (chlorosis) of the younger leaves. Mild iron deficiency appears as interveinal chlorosis and is often confused with manganese deficiency. If the deficiency is severe and prolonged, each new leaf emerges lighter in color than the preceding leaf.

Soil Analysis

Iron deficiency is extremely rare in Wisconsin field crops. For this reason, no soil test for iron has been developed. If iron deficiency is suspected, plant analysis can verify the deficiency.

Plant Analysis

Analysis of plant tissue for iron is not as reliable as it is for other nutrients, because plant tissue commonly is contaminated with iron-containing soil from dust or from soil splashed on by raindrops. Use special care when collecting these samples to ensure that they are not contaminated with soil. Also, some physiologists feel that “total” iron in tissue is a poor indicator of plant needs. Table 2 gives guidelines for interpreting iron concentrations in some field crops. If visible symptoms are not apparent, response to iron is unlikely.

ADDITIONAL INFORMATION

These publications in the *Understanding Plant Nutrients* series are available from your county Extension office:

Soil and Applied Boron	(A2522)
Soil and Applied Calcium	(A2523)
Soil and Applied Chlorine	(A3556)
Soil and Applied Copper	(A2527)
Soil and Applied Iron	(A3554)
Soil and Applied Magnesium	(A2524)
Soil and Applied Manganese	(A2526)
Soil and Applied Molybdenum	(A3555)
Soil and Applied Nitrogen	(A2519)
Soil and Applied Phosphorus	(A2520)
Soil and Applied Potassium	(A2521)
Soil and Applied Sulfur	(A2525)
Soil and Applied Zinc	(A2528)

Table 2. Iron plant-analysis interpretations for common Wisconsin crops.

			INTERPRETATION			
CROP	PLANT PART SAMPLED	TIME OF SAMPLING	DEFICIENT	LOW	SUFFICIENT	HIGH
			ppm			
Alfalfa	Top 6 inches	Bud	<20	20–30	31–250	>250
Corn	Earleaf	Silking	<10	10–50	51–250	>250
Oat, wheat	Top leaves	Boot stage	—	<20	20–250	>250
Potato	Top leaves	Flowering	—	<11	11–300	>300
Soybean	First trifoliate	Early flower	<30	30–50	51–350	>350

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