Iron Deficiency Chlorosis IN WYOMING

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Soils in the Rocky Mountain West developed under arid conditions from materials that contain limestone. These soils are typically high in free lime (calcium carbonate), which causes them to be alkaline. In addition, many of our soils do not allow good movement of air and water within the root zone due to their high clay content and low organic matter levels. These factors, which are products of the area climate and geology, may limit the availability of certain soil nutrients and cause nutrient deficiencies. Iron deficiency is the most common of these.

What causes iron deficiency?

Iron (chemical symbol Fe) is one of 16 chemical elements essential for plant growth. Known as a micronutrient, iron is required by plants in small amounts, relative to other nutrients such as nitrogen (N), phosphorus (P), and potassium (K). Other micronutrients include boron (B), chloride (Cl), copper (Cu), manganese (Mn), molybdenum (Mo), and zinc (Zn). Iron is abundant in most soils, but as with other micronutrients, its availability is greatly influenced by soil conditions. Soil pH is one characteristic that has a considerable influence. Iron availability is lowest between pH 7.5 and 8.5. It becomes more available to plants as soil pH decreases.

The pH of a soil is a measure of its alkalinity or acidity and is measured on a scale of 1 to 14, where a value of 7 is neutral. Values less than 7 are acid, and those greater than 7 are basic or alkaline (Table 1). Wyoming soils usually have pH values between 7.0 and 8.5, with some greater than 9.0. The availability of iron is greatly reduced when alkalinity is this high. This effect is aggravated by cool, wet soils that can occur during the spring. Heavy soils, high in clay con-

Table 1. pH values of some common materials

pH	Material	Acid or alkaline
14.0	Sodium hydroxide	Alkaline
13.0	Lye	Alkaline
12.4	Lime	Alkaline
11.0	Ammonia	Alkaline
10.5	Milk of magnesia	Alkaline
8.3	Baking soda	Alkaline
7.4	Human blood	Alkaline
7.0	Pure water*	Neutral
6.6	Milk	Acid
4.5	Tomatoes	Acid
4.0	Wine and beer	Acid
3.0	Apples	Acid
2.2	Vinegar	Acid
2.0	Lemon juice	Acid
1.0	Battery acid	Acid
0.0	Hydrochloric acid	Acid

**Pure water is very rare; most supplies will have at least some impurities.*

tent and low in organic matter, are more susceptible to iron deficiency than soils containing more silt or organic matter.

The type of plant influences whether or not iron deficiency chlorosis will be a problem. Some plant species can extract enough iron for growth from high-pH soils. Plants native to areas with acid to neutral soils are more likely to exhibit iron deficiency when grown in alkaline soils. There are even differences among varieties of the same species.

What are the symptoms of iron deficiency?

Plants suffering from iron deficiency show distinct symptoms; the most obvious is interveinal chlorosis. Chlorosis is a general term used to describe abnormally yellow leaves. Chlorosis caused by iron deficiency is usually restricted to the leaf tissue between the veins, while the veins themselves remain green (Figures 1, 2, 3).

The yellowing develops because iron is used in the production of chlorophyll (the pigment that gives leaves their green color). Iron doesn't move within plants, and even healthy plants cannot take iron from older leaves and send it to younger leaves. In iron deficient plants, the levels of iron in younger leaves are too low for normal chlorophyll production, and chlorosis first appears on new growth. As the deficiency progresses, it may also affect older leaves.

In severe cases of iron deficiency, leaves will be smaller than normal, will turn pale yellow, and will develop angular brown spots between the veins. Leaf margins may also turn brown. The entire leaf may die prematurely if the condition is not corrected. The ends of branches also die back on some broadleaf trees. In general, plants affected by iron deficiency will be stunted and weak. This condition makes them more susceptible to disease and insect damage. Symptoms will often be more pronounced on the sun-stressed side of a tree (south or west exposure) and on plants near areas of newly poured concrete.

How can iron deficiency chlorosis be prevented?

Proper selection of plant material is the best strategy for preventing iron deficiency chlorosis. All too often, plants are chosen with little thought about the sites where they are to be planted. Plant species differ widely in their tolerance of soil conditions that cause iron deficiency. Although plant species that are susceptible are numerous and cross all plant families, tolerant plants species are also available (Table 2). As a general rule, most of the plant species native to our region will have some tolerance to alkaline soils and iron deficiency. (See University of Wyoming Extension Bulletin B-1090, Landscaping: Recommended Trees for Wyoming and Bulletin B-1108, Landscaping: Recommended Shrubs for Wyoming.)

Use good planting procedures once the appropriate plant material has been selected. Follow the recommended planting methods for any new plants, whether woody or herbaceous. Finally, water and fertilize according to the needs of the plant. Inadequate water will cause drought stress and limit the effectiveness of fertilizer materials, as nutrients must be dissolved in water for the plant to absorb them. Conversely, overwatering will cause the soil to remain waterlogged and will reduce air exchange between the atmosphere and the root zone, a condition that will aggravate iron deficiency problems.

Figure 1. Iron chlorosis on Kentucky coffeetree *(Gymnocladus dioicus).*

Table 2. Plant susceptible to or tolerant of alkaline pH conditions in the soil.

Susceptible to iron chlorosis in alkaline soils	Tolerant of alkaline soils
Maples	Catalpa
Oaks	Hackberry
Aspens	Many junipers
Cottonwoods	Lilacs
Rose family (Rosaceae)	Many *Prunus* species
Pines	Viburnums
Ohio buckeye	Caragana (peashrub)

What are the best strategies for treating iron chlorosis?

When iron deficiency chlorosis is caused by cool, wet weather or by improper watering, the symptoms will usually disappear when the weather improves or when the watering problem is corrected. Often, a chlorotic plant can manage for an extended period of time without treatment. Treatment may not be necessary if the condition does not worsen over time and the plant's appearance is acceptable to its owner.

Severe iron deficiency is rarely reversible. In more moderate cases, treating iron chlorosis requires an integrated approach. Adequate levels of other nutrients in proper balance must be present for the plant to efficiently utilize any applied iron fertilizer. A soil test will identify nutrient needs and other soil factors important in determining how to deal with an iron problem.

Soil treatments: Soils pH 6.8-7.2

Most Wyoming soils will not fall into this category. When the soil pH is in the 6.8 to 7.2 range and the free lime (calcium carbonate) content is low, the soil will often respond to an annual broadcast treatment of 10 pounds of ammonium sulfate per 1,000 square feet or 25 pounds of sulfur per 1,000 square feet. This treatment will temporarily lower the pH and make the iron in the soil more available to the plants. Liquid fertilizers applied to the soil will be taken up by the plant more quickly.

Soil treatments: Soils pH>7.2

Most Wyoming soils do fall into this category. Broadcast application of iron sulfate is often ineffective on soil with a pH above 7.2. For use with trees and shrubs, the availability of this form of iron can sometimes by improved by inserting plugs of iron sulfate and sulfur in holes, spaced about 2 feet apart, along the drip line of a tree. The holes should

Figure 2. Iron chlorosis on ponderosa pine *(Pinus ponderosa).*

Figure 3. Iron chlorosis on crabapple *(Malus sp.)*

be about 2 inches in diameter and 6 to 9 inches deep. Mix equal amounts of iron sulfate and sulfur. Place ¼ pound of the mixture into each hole, and then cover with soil. Even this method may not be effective with high-pH or high-lime soils. Chelated iron should be used for these soil types.

Chelating combines iron with an organic compound that keeps it available to plants when applied to the soil. There are many different chelated fertilizers on the market. Chelated iron in the form of FeEDDHA is effective across the entire pH range of Wyoming soils. Other types of chelated iron are less effective at higher pH levels. Again, the plant will take up liquid fertilizers more rapidly than those in a dry form. Always read and follow the label directions carefully.

Foliar applications

Soil applications of iron fertilizers usually require some time to become effective. This means the plant continues to be under nutrient stress, which increases its susceptibility to drought, disease, and insect damage in the interim. Iron can be sprayed on the foliage either as inorganic ferrous sulfate or as chelated iron. Sprays can be done at 10-day intervals during the active growing period.

To use iron sulfate, mix 1.25 ounces of iron sulfate with 1 gallon of water. A wetting agent, available from many horticultural supply companies, should be added to the mixture. Follow the wetting agent product directions for the appropriate amount. Thoroughly wet the foliage with the mixture. Chelated iron can also be sprayed on the foliage. Follow the product directions on the label. Never apply a foliar spray when the temperature is likely to exceed 90 degrees Fahrenheit within 24 hours of application. Foliar application should stop when chlorosis disappears. Leaf damage can occur even when all the proper precautions are taken. Iron sprays can also leave an orange or rust-colored residue on foliage, sidewalks, driveways, and buildings. Always mix up only the amount of fertilizer needed, use all of the mixture, and never store leftover fertilizer mixture. High-pH water may decrease the effectiveness of the fertilizer if it is not used right away.

Injections

Occasionally, soil fertilization and foliar application will not alleviate iron chlorosis symptoms in woody plants. In these cases, it may be necessary to consider direct trunk injection of iron on 3-inch or larger diameter trunks. Keep in mind, however, injections require creation of open wounds in tree trunks. Creating an open wound in a woody plant increases the potential for disease or insect damage. Injections should only be done by a Certified Arborist. To find a list of Certified Arborists, check the International Society of Arboriculture website Find an Arborist link (http://www.isa-arbor.com/findanarborist/arboristsearch.aspx).

Finally, if the plant does not respond positively, consider replacing it with a species tolerant of alkaline or high-pH soils. Contact your local University of Wyoming Extension office or your nursery professional for plant suggestions.

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