Plant Materials Program

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IRON (Fe) CHLOROSIS IN PLANTS

Have you noticed that some of your conservation and landscape plants have yellow leaves this year? A common plant micronutrient imbalance in the northern Great Plains and Snake River Plains is iron (Fe) deficiency, an imbalance that leads to iron or *lime-induced* chlorosis. The term *chlorosis* describes foliage that is yellow in color, the result of inadequate chlorophyll production. Chlorosis can result from any one of several factors and multiple nutrient imbalances, not merely iron deficiency. The specific type or pattern of chlorosis varies by cause and species, and can be helpful in determining the causal agent. Symptoms vary from yellowing of the entire leaf, the younger leaves, older leaves, leaf edges, between the veins, as irregular spots, or as a mosaic pattern. Iron deficiency induced chlorosis often appears as yellowing along the leaf margin and between the leaf veins. Since the veins themselves typically remain green, this condition is referred to as "interveinal chlorosis." In severe cases, the entire leaf becomes pale yellow, the tips turning brown to almost black if untreated. Iron chlorosis appears on the youngest leaves because the element is very immobile within the plant, and is not translocated from older tissue as needed. One or more limbs may be affected while others appear normal.

Iron is a component of several substances that play key roles in plant physiology. One very important role is in the synthesis and degradation of chlorophyll, although iron itself is not a constituent of the chlorophyll molecule. Chlorophyll in turn plays an important role in plant carbohydrate metabolism via photosynthesis (food production). When iron is lacking in the soil or is in an insoluble form, chlorosis may result. As mentioned earlier, there are many factors that contribute to chlorosis including genetics, ion imbalances, light intensity, oxygen level, carbohydrate availability, as well as nitrogen, magnesium, manganese, copper, and zinc availability. Temperature and water availability also influence chlorophyll production and chlorosis. In other cases, root injury by tilling or even drought may cause decreased iron uptake and chlorosis. Sandy soils low in organic matter may also be iron deficient. The heavy use of copper fungicides on sandy soils has also been reported to induce iron deficiency. In many cases, susceptible species planted near foundations, concrete walkways, and other cement structures containing or contaminated with lime from mortar show symptoms of iron deficiency. This may be the result of high lime subsoils used as backfill, or directly from lime residue or leaching.

Most soils in Montana, Wyoming, Idaho, and Utah are not iron deficient. The primary cause of iron deficiency in plants in these areas results from a lack of soluble or available iron in soil solution. Mineral elements vary in their solubility as soil pH varies. Iron solubility in soil solution decreases to a minimum on soils with a pH of approximately 7.5 to 8.5, a range that is common in soils in the western United States. Keep in mind that Fe^{3+} (ferric iron) and Fe^{2+} (ferrous iron) activity in soil solution decreases 1000-fold and 100-fold, respectively, for each unit increase in pH. Some particularly sensitive plants even demonstrate chlorosis on acid soils. Iron deficiencies may be aggravated by high levels of HCO_3^- (bicarbonate ion) in irrigation water or soils, simply as a result of high pH, or because of the presence of the ion itself. High levels of calcium carbonate, calcite, and dolomite (calcium carbonate, magnesium carbonate) also coincide with high soil pH, high incidence of iron deficiency, and low soluble soil iron. Compacted, heavy-textured, calcareous soils often provide the high moisture, poor aeration conditions that favor the conversion of calcium carbonate to bicarbonate via the reaction

$CaCO_3 + CO_2 + H_20 \rightarrow Ca^{2+} + 2HC0_3^-$. Imbalances of other ions also influence iron availability. Excess levels of copper, zinc, or manganese also promote iron deficiency. Large amounts of limestone or ash, insufficient potassium (K), or excessive phosphorus (P) can also lead to iron chlorosis.

Several crops are known to be sensitive to low iron levels including numerous berry-producing species (especially raspberry), field beans, various fruit trees, grapes, mint, and some vegetables. Plants such as alfalfa, barley, corn, grasses, oats, millet, potatoes, sugar beets, wheat, and some vegetables are considered moderately tolerant to tolerant. Many native species, especially woody plants, that grow naturally on higher elevation forestlands characterized by acidic, well-drained soils develop iron deficiency when grown on alkaline, heavy-textured soils typical of valley bottomlands. Iron chlorosis has been observed on high pH soils in amur maple (*Acer ginnala*), silver maple (*Acer saccharinum*), mountainash (*Sorbus scopulina*), European mountainash (*Sorbus aucuparia*), aspen (*Populus tremuloides*), cottonwood species (*Populus* species), Scotch pine (*Pinus sylvestris*), numerous ornamental spireas (*Spiraea* species), shrubby penstemon (*Penstemon fruticosa*), day lilies (*Hemerocallis* species), junipers (*Juniperus* species), and more. Raspberries (*Rubus*) are particularly sensitive and are reported to start showing signs of iron deficiency at a soil pH as low as 6.5. The numerous and varied lists of susceptible species suggests that some populations of a given species are less susceptible to iron chlorosis than others, and/or that multiple environmental interactions at any given place may affect susceptibility.

Overcoming iron deficiency in plants on alkaline and calcareous soils is somewhat of a long-term commitment. The condition is essentially chronic, and requires periodic if not regular inputs of labor and materials. The best strategy on new plantings is to select species that are adapted to the planting site, especially species and cultivars growing well under similar environmental and soil conditions. In an established planting, it may prove profitable in the long term to replace small or inexpensive plants that are susceptible to iron chlorosis with non-susceptible substitutions. For small localized areas, it may even be practical to remove high pH or lime contaminated soil and replace it with a clean soil of acidic reaction. Improving drainage on heavy textured or excessively wet soils and leaching of high salt content soils is often needed before iron supplements prove effective.

If an established plant is iron deficient, there are several cultural techniques that will alleviate the disorder, if only for a period of time. The quickest and most absolute solution is to treat the soil and foliage with an iron fertilizer. There are numerous methods of delivering iron fertilizers including application to the soil surface, injection or incorporation into the soil, spraying onto the leaves and bark, and injection or implantation in trunks and large branches. There are also various formulations, concentrations, and types of iron compounds that can be used. Soil-applications of inorganic salts such as ferrous iron compounds often produce marginal results because they are rapidly oxidized to the much less soluble ferric iron form. Foliar sprays ranging from 2 to 20 percent iron sulfate or, synthetic chelated iron or soluble organic iron complex are generally more effective. Response time can vary from fairly short for herbaceous species to quite long for woody plants, with results seldom lasting more than one growing season. Multiple applications, beginning in the early spring, are usually necessary. Chelated compounds are more plant available, the iron being bound in large organic molecules that prevent oxidation to the less soluble ferric form. Chelated compounds are labeled with a series of capital letters following the iron symbol (Fe), such as Fe-EDDHA. The stability of each chelate varies with soil reaction. As an example, CDTA is less stable than DTPA, which in turn is less stable than EDDHA as pH rises above neutral (7.0). The specific chelate used varies with the type of application. Fe-DTPA is often used in foliar applications whereas Fe-EDDHA is used for soil treatment. Both foliar and soil efficacy is improved by adding a nitrogen source and wetting agent. For trees and large shrubs, implants of ferric ammonium citrate and ferrous sulfate in gelatin capsules have proven effective. Injection of a 1% ferrous sulfate solution at 200 to 300 psi in fruit trees has provided adequate iron fertility for several years. Both implantation and injection should be done by a qualified arborist. Visit your local Extension office, Community/Urban forester, nursery, garden center, or tree service for specific product information and recommendations. Follow fertilizer label recommendations carefully, too much fertilizer is worse than not enough product.

As an interesting side note, the organic farming community has expressed concern over background levels of arsenic, cadmium, and lead in many fertilizers, particularly iron compounds. Elemental iron is bound, along with the aforementioned heavy metals, in the ore that is processed to make iron fertilizers. Depending on the product, these levels can be quite high.

Another strategy for reducing iron chlorosis involves increasing iron solubility by lowering soil pH. Products such as elemental sulfur, ammonium thiosulfate, sulfuric acid, ammonium bisulfite, sulfur dioxide, and ammonium polysulfide have been used to reduce ferric iron to the more readily available ferrous form. This may temporarily correct an iron solubility problem on a small area, but it is not a practical or cost efficient solution for large areas.

Soil amendments may also improve iron availability. The incorporation of organic matter improves drainage and oxygen levels on water-logged, calcareous soils which in turn increases root growth and improves iron uptake. In some cases, it may even prove helpful to moderate irrigation of heavily mulched plantings covered with landscape fabric, especially non-perforated sheet plastic. Soil moisture often remains high under mulch and fabric, and may promote conditions that reduce iron solubility. The results of organic matter additions on well-drained soils are more variable. It is theorized that although organic matter may improve iron availability by supplying natural chelating agents, there may be some resultant soil chemistry that offsets these gains. Soil amendment with gypsum can improve iron availability by reducing the interference of molybdenum on iron uptake on high pH soils.

In summary, here are a few helpful hints when correcting an iron chlorosis problem:

1) Select plants that are not susceptible to iron chlorosis.
2) Correct poor soil drainage. Allow excessively wet soils to dry out between irrigations.
3) Add organic matter, especially composted products such as leaves and manure, to excessively wet soils.
4) Begin fertilization early in the growing season and repeat at 2- to 3-week intervals.
5) Use chelated iron compounds.
6) Compare the chemical analysis and recommended rate of various commercial products to determine the best value. Keep in mind that the form of iron is also an important factor.

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