Utilizing Iron In Turfgrass Management

David Wehner, Ph.D.
University of Illinois, Urbana-Champaign

Dr. George Wallace — a researcher from UCLA, writing in *HortScience* — called the 1980s the decade for advancement in our knowledge of iron (Fe) and plant nutrition.

He states:

"More progress was perhaps made in the 1980s on understanding and management of Fe chlorosis in plants than during the previous 150 years since it became known that Fe deficiency was involved in the chlorosis."

Iron is used in a broad range of applications by turfgrass managers including treating iron deficiencies and using it to enhance color. Although much of the research to which Dr. Wallace was referring was conducted on species other than turfgrasses, his statement emphasizes the importance of understanding soil-plant-iron relationships. His conclusion was based on the significant advances that scientists made during this time in understanding iron uptake mechanisms and how iron deficiences influence plants.

The purpose of this article is to review some of the basic information on iron, look at one of the discoveries made during the 1980s, and present some of the published research studies that have been conducted with iron on turfgrasses. Additional information on the use of iron can be found in popular magazines and in the proceedings of turfgrass conferences.

Iron is one of the 16 elements required for plant growth. It is classified as a micronutrient, which means that it is needed in a relatively small amount by the plant. Iron functions in various physiological roles. For instance, it is a component of proteins and enzymes involved in respiration, nitrogen metabolism and in the synthesis of chlorophyll, even though it is not a part of the chlorophyll molecule. Yust (1982) and Harivandi (1987) have listed causes for turfgrass iron deficiencies. The terms iron deficiency, iron stress and iron chlorosis will be used interchangeably throughout this discussion.

David Wehner is an associate professor in the department of horticulture.

Iron deficiency in turfgrass is symptomized by appearance of interveinal chlorosis. As severity increases, entire leaf will become chlorotic and may appear bleached.

Causes Of Iron Deficiencies

There are many soil-related causes of iron deficiency. Some of the most common causes are:

- A deficiency of iron in the soil. Although most soils contain adequate levels of iron, the iron may be unavailable to the plant. A sand-based putting green may become iron-deficient because of low nutrient holding capacity and frequent irrigation. Scientists have observed growth responses from iron applications, just as you might expect from any other fertilizer, even when there has not been an observable deficiency symptom.
- An imbalance or interaction between Fe and other micronutrients. Imbalances between the levels of copper, zinc, manganese and iron can reduce iron uptake.
- A high soil phosphorus content. Phosphorus can form insoluble iron phosphates at a low soil pH or cause iron deposition on the surface of roots at high pH.
- A presence of high levels of calcium carbonate or the bicarbonate ion in the soil or in irrigation water. Iron availability is greatly reduced at high soil pH which occurs in the presence of calcium carbonate in the soil. This problem is called lime-induced chlorosis. Iron chlorosis also can result from application of irrigation water with a high bicarbonate ion concentration.

In addition, there are several plant-related causes of iron deficiency. Some of the most common causes include:

- A poor root system. Plants that have poor root systems as a result of insects or disease, excessive thatch, improper mowing, excessive N fertilization or other causes may not absorb enough iron, particularly if a soil-related factor also is present.
- The presence of a cultivar that is susceptible to iron chlorosis. Cultivars differ in their ability to tolerate low levels of iron. The increased productivity of turfgrass breeders during the last 10 years has resulted in the release of many cultivars that have not been characterized for their susceptibility to iron stress. Harivandi and Butler (1980) reported that the Kentucky bluegrass cultivars Adelphi, Sodco, Sydsport and Windsor provided good color while Merion, Warren's A-20, Park, Arboretum, Nugget and Bensun provided poor color in a field study under low iron conditions. In another study, McCaslin et al. (1981) screened 81 cultivars of bermudagrass for iron efficiency by growing them in a low iron soil in pots in a greenhouse. Of the named cultivars tested, they reported high color ratings for Tifway and Tifgreen bermudagrass and intermediate color ratings for Westwood and Tufcote. Top growth production did not correlate with iron efficiency as judged by the color ratings.

Iron deficiency symptoms show up as a chlorosis in the younger, upper leaves of the plant in contrast to N deficiencies, which result in chlorosis of the older, lower leaves. Harivandi (1987) reported

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that iron deficiencies on turf are not uniform over an entire area, but occur in a random pattern, which gives a mottled appearance. Nitrogen deficiencies, on the other hand, appear as uniform yellowing over a large turf area.

The use of tissue tests to determine if an Fe deficiency problem is present has been somewhat difficult because the iron content of the tissue may not correlate with the appearance of the turf. In addition, the tissue concentration in apparently healthy turf can change during the course of the season. Some researchers have reported good correlations with iron content and turf color while others have not found this to be the case. Total Fe content in chlorotic leaves of some Kentucky bluegrass cultivars was found to be higher than in leaves of other cultivars that were less chlorotic by Pierson et al. (1986). Therefore, superintendents should familiarize themselves with the conditions that may lead to Fe chlorosis and be aware of how the turf might appear in these situations so that they can rapidly diagnose the problem. Again, it is important to remember that Fe applications can cause a growth response even though the leaves are not chlorotic.

Treating Iron Deficiencies

The treatment of an iron deficiency may be as simple as an occasional application of an iron fertilizer or as complex as dealing with a high concentration of bicarbonate ion in an irrigation supply. If the potential exists for iron deficiencies to occur, the superintendent should thoroughly investigate all possible alternatives before establishing a turfgrass site. These alternatives might include selecting an iron efficient cultivar or, when constructing a putting green, selecting a sand with a low concentration of calcium carbonate, for example. It also may be possible to change a management practice that is weakening the root system and resulting in insufficient iron in the turf.

The three most common approaches to dealing with iron problems through fertilization or application of other materials have been:

- A foliar spray of Fe at a relatively low rate (1-4 lbs. Fe/acre).
- A soil application of an iron-containing fertilizer at a relatively high rate.
- An application of a strongly acidifying fertilizer.

Kentucky bluegrass one week after treatment with excessive rate of ferrous sulfate shows some recovery from injury.

The most common forms of iron fertilizers are inorganic iron salts and organic iron chelates. An iron salt is a water soluble form of iron that contains iron or iron and ammonium as the cations paired with an anion such as sulfate (e.g. ferrous sulfate, ferric sulfate or ferrous ammonium sulfate). Iron salts applied to the soil are rapidly converted to insoluble iron hydroxides, iron phosphates or iron carbonates. A chelated source of iron contains an iron molecule surrounded by an organic complexing agent that allows the iron to be more available to the plant. The acid-containing materials provide some iron to the plant, and also help to lower the pH of the root zone, which makes the iron in the soil more available.

The most frequently cited research regarding correcting iron deficiencies with fertilization was conducted by Minner and Butler (1984). They applied several iron salts, iron chelates, and acidic-treated mine tailings (pH 1.9) to iron-deficient Kentucky bluegrass and evaluated turf color. Their results showed that foliar sprays of iron chelates (4.3 lbs. Fe/acre) or a soil application of ferrous ammonium sulfate, ferrous sulfate or the acid-treated mine tailings (all at 21.4 lbs. Fe/acre) corrected the deficiency. The main difference between the foliar applications and the soil treatments was that the soil treatments resulted in improved color for more than a year. In a second experiment, ferrous sulfate was applied as a granular treatment to the soil at rates of 10.7, 21.4, 42.9 and 85.7 lbs. Fe/acre. Turf color improved with applications up to 42.9 lbs. Fe/acre). However, Harivandi (1987) cautions that a treatment of 0.5 to 1 lb. of actual iron/1,000 sq. ft. from ferrous sulfate or ferrous ammonium sulfate on turfgrasses may cause severe and long-lasting burns. Because of this, frequent light applications are probably more desirable.

The fact that Minner and Butler (1984) still observed a turfgrass response one year after application of ferrous sulfate and ferrous ammonium sulfate requires some speculation. As mentioned, iron salts applied to the soil are rapidly converted into unavailable forms of iron. The prolonged response in this case may have been due to the greatly increased presence of iron compounds in the upper surface layers of soil or the fact that the turf was composed of Pennstar and Fylking, which were characterized by Harivandi and Butler (1980) as only moderately susceptible to iron chlorosis. In addition, this response may have occurred because the large applications of either material may have slightly acidified the soil.

Breakthroughs In Iron Research

Probably the most interesting development regarding iron nutrition in plants was the elucidation of two different mechanisms that are responsible for iron uptake (Marschner et al., 1986). The scientists characterized plants as having either Strategy I or Strategy II mechanisms for iron uptake. Strategy II plants, the group to which most grasses are thought to belong, have a mechanism where the plant roots excrete a substance called a phytosiderophore.

Phytosiderophores are nonproteinogenic amino acids (amino acids other than those found in proteins) that have the ability to solubilize and combine with iron from sparingly soluble inorganic iron compounds such as iron hydroxide. The plant is then able to take up the Fe-phytosiderophore complex. Interestingly, different susceptibilities to iron chlorosis among species and cultivars are thought to be related to the degree to which this mechanism is present in the plant. The researchers demonstrated this by placing an iron-deficient barley plant, a species with a high rate of release of phytosiderophores, in combination with an iron-deficient sorghum plant, a species with a low rate of release of phytosiderophores, in a solution culture system. They

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found that the sorghum plant greatly increased its uptake of iron. Currently, however, there is no information available regarding the presence of this mechanism in turfgrass cultivars that shows differential susceptibility to iron chlorosis.

Using Iron To Improve Turfgrass Color And Growth

In many parts of the United States, iron deficiencies are rare. In these areas, iron is used to enhance the color of the turfgrass stand in the absence of, or with reduced applications of N. Golf course superintendents probably have more experience with the use of iron in this way than any other group in the turfgrass industry. The response of turfgrass to iron applications will depend on the rate of Fe applied, the growth rate of the turfgrass, and the sensitivity of the particular species to foliar injury from iron applications.

Creeping bentgrass. Researchers in Virginia (Snyder and Schmidt, 1974) have reported on the use of Fe applications in combination with N on creeping bentgrass. They reported a beneficial effect on spring color, clipping yield, root growth and chlorophyll content from iron (iron chelate, NaFeDTPA, 1.1. lbs. Fe/acre per application) and nitrogen (1 lb. N/1,000 sq. ft.) applied several times during the fall and winter months. In later studies conducted in the growth chamber (Schmidt and Snyder, 1984), they evaluated the relationship between N level, moisture stress, temperature and iron application on the growth and physiology of creeping bentgrass. They found that foliar applications of iron chelate increased top growth during cool temperatures. As temperatures were raised, however, iron chelate applications decreased top growth. The iron chelate applications enhanced turfgrass color on all sampling dates.

Kentucky bluegrass. Research conducted by Yust et al. (1984) looked at applications of ferrous sulfate and iron chelate (NaFeDTPA) with and without N on Kentucky bluegrass. Color enhancement from iron applications without N lasted from several weeks when the turf was growing rapidly, to several months when the turf was growing slowly. It also was reported that the color enhancement provided by N (0.5 lb. N/1,000 sq. ft.) in combination with iron (1, 2 or 4 lbs. Fe/acre) was equivalent to the color enhancement from a higher rate of N (1 lb. N/1,000 sq. ft.) The treatment of 2 lbs. Fe/acre from iron chelate was judged to be the most effective Fe treatment because the color enhancement was usually equal to that provided by the 4 lb. Fe rate of either source, but did not result in any discoloration as was sometimes found with this rate. Finally, applications of high rates of iron, while resulting in significant foliar phytotoxicity, did not result in the death of the turfgrass plants.

Centipedegrass. Interest in improving centipedegrass color, which is naturally yellow-green, has led researchers to apply Fe and N combinations as foliar sprays. Carrow et al. (1988) reported that the color of centipedegrass can be enhanced with applications of N and Fe (NaFeDTPA), but that this species is very sensitive to the rates of application as influenced by the temperature during application. They reported that when the temperatures on the date of treatment ranged from 71 F to 91 F, 1.8 lbs. Fe/acre could be used in conjunction with up to 0.2 lb. N/1,000 sq. ft. without objectionable phytotoxicity such as blackening of the turf. This iron rate resulted in color enhancement for as long as 35 days. When the N rate was increased to 0.8 lb. N/1,000 sq. ft., somewhat less than 0.9 lb. Fe/acre was the greatest rate that could be used. When the temperature on the date of treatment ranged from 82 F to 99 F, only 0.65 lbs. Fe/acre could be used with 0.25 lb. N/1,000 sq. ft. When the N was increased to 0.5 lb./1,000 sq. ft., no Fe could be applied since the N alone caused objectionable burn. The 0.65-lb. Fe treatment resulted in color enhancement for up to 22 days.

Iron And Bermudagrass Response To Chilling Temperatures

Richard White and Richard Schmidt (1988, 1989) have investigated the response of bermudagrass to chilling temperatures (32 F to 59 F) as influenced by applications of iron. Bermudagrass produces minimal growth and is discolored by chilling temperatures. Various physiological parameters were monitored

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Some iron sources used as fertilizers. (Adapted from Mortvedt, 1991)

Source	Formula or Designation	Chemical Name	% Fe (approx.)
Ferrous sulfate	$FeSO_4 7H_2O$		20
Ferric sulfate	$Fe_2(SO_4)_3 4H_2O$		23
Ferrous ammonium sulfate	$FeSO_4(NH_4)_2SO_4 6H_2O$		14
Iron Chelates	NaFeEDTA	Sodium ferric ethylene diamine tetraacetate	5-14
	NaFeHEDTA	Sodium ferric hydroxyethylene diamine tetraacetate	5-12
	NaFeDTPA	Sodium ferric diethylene triamine pentaacetate	10
	NaFeEDDHA	Sodium ferric ethylene diamine di (o-hydroxy phenylacetate)	6
Iron frits			10-40
Iron lignosulfates			4-8
Iron phenols			6-10
Iron polyflavonoids			9-11

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in their growth chamber studies. In the 1988 study, application of Fe (NaFeDTPA) equivalent to 1.0 lb. Fe/acre resulted in increased photosynthetic rates before, during and after chilling, and resulted in higher color ratings after the chilling period. In the 1989 study, which involved Midiron, a chill-tolerant bermudagrass, and Tifgreen, a chill-sensitive cultivar, two applications of iron at a rate equivalent to 0.5 lb. Fe/acre were made prior to the chilling treatment. Iron applications resulted in maintenance of the aesthetic quality of both bermudagrasses after the chilling period and recovery of daytime and nighttime carbon dioxide exchange rates. The researchers concluded that foliar applications of Fe should be beneficial for maintenance of more desirable bermudagrass turf quality levels during exposure to chilling temperatures.

Using Iron To Reduce Pesticide Injury

Frequently, pesticide applications can discolor turfgrass during the process of removing the unwanted pest. Applications of iron in combination with a pesticide can sometimes moderate the effect of a pesticide on turf color. Johnson et al. (1990) included chelated Fe (iron phosphate-citrate, 1.0 lb. Fe/acre) applications either immediately after or as tank mixes with MSMA (monosodium methane arsenate), MSMA + metribuzin (Sencor), MSMA + imazaquin (Image), imazaquin, and 2,4-D + MCPP + Dicamba to Tifway bermudagrass. In most cases, bermudagrass color and quality were improved when Fe was added. Injury expressed as loss of shoot density was not affected by Fe. Iron did not prevent immediate 2,4-D + MCPP + Dicamba injury, but did hasten turf recovery from injury 26 days after treatment.

Carrow and Johnson (1990) have reported on the use of Fe (ferrous sulfate, 0.65 or 1.3 lbs. Fe/acre) with applications of growth regulators to suppress seedhead development on centipedegrass. Applications of the growth regulators mefluidide (Embark) and mefluidide + flurprimidol (Cutless) caused yellowing of centipedegrass in one of the two years during which they were applied. The inclusion of Fe with the growth regulator treatments eliminated the color loss.

Kentucky bluegrass treated with excessive rates of ferrous sulfate (foreground) and iron chelate (background) shows impact 24 hours after application (foliar).

It is important to note that some forms of iron can interact with pesticides to reduce effectiveness or increase foliar phytotoxicity. The superintendent should check for precipitates and evaluate tank mixes of pesticides with iron on a small area before applying the mix to large acreages. It is well known that the inclusion of ferrous sulfate with mixes of 2, 4-D + MCPP + Dicamba will deactivate a portion of the herbicide. Turfgrass managers using Fe to enhance the color of the turf should test a rate of approximately 1 lb. Fe/acre on a small area to determine if it will produce the intended result. Remember, some turfgrass species are more sensitive to Fe applications than others and over-application may cause a blackish coloration on the turf.

Because of its versatility, iron currently is being used in a broad range of applications by superintendents managing cool-season and warm-season turfgrasses. The problem of Fe chlorosis, however, is widespread in the western and southwestern regions of the United States where golf development is very active. Many superintendents also are managing greens that have been constructed with a high percentage of sand in the root zone. In addition, as more courses are irrigated with water of marginal quality, the number of Fe-related problems can be expected to increase. As a result, an understanding of the role of iron in the turfgrass plant, the availability of iron in the soil and the application of iron fertilizers will become even more important to the superintendent in the future. ☐

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