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Soil and Tissue Testing and Interpretation for Florida Turfgrasses[1]

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Most people agree that healthy, well-maintained turfgrass is a thing of beauty. However, many of these same people think beautiful turfgrass requires lot of trouble, hard work, and possibly demanding expertise which they do not possess. This is not necessarily true, but a few basic facts concerning the nutritional requirements of turfgrasses and the properties of fertilizer and liming materials are essential. Water and pest infestation may influence turfgrass growth and quality, but more often lawns suffer from nutritional deficiencies and it is essential that one know how to address these maintenance requirements.

Florida soils are predominately sandy and have a low capacity for nutrient retention. Thus, the application of fertilizer nutrients may be required on a regular and continuing basis to maintain the nutritional needs of the turfgrass. Except for the calcareous soils of south Florida, the state's soils are predominately acidic. A liming material may need to be applied in many cases to neutralize a portion of this acidity to obtain optimum growth and color of the turfgrasses. Nutritional requirements of turfgrasses and suggested soil test levels for the various nutrients are presented in the following sections.

Soil Test Philosophy

Soil testing is an applied science and can be used as one of the tools in the maintenance of a healthy turfgrass. Soil testing should be used in conjunction with tissue testing to arrive at the optimum fertility maintenance program for your turfgrass. Many things influence the level of nutrient extracted from a soil sample, the quantity taken up by the plant and the observed response. The soil test and the resulting recommendations represent the turfgrass production area only as well as the sample itself. Therefore, it is imperative that the soil sample be taken and handled properly. The quantity of a target nutrient extracted depends on several mostly uncontrollable soil factors, but the nutrient recommendations are based on the plant growth responses which have been correlated with the levels of nutrients extracted in a soil test. The levels of P, K and Mg are divided into five categories: very low, low, medium, high and very high. Recommendations are based on statistical probability of response to an application at the various levels of nutrient extracted as follows: a very low level of

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nutrient implies that there is a 75% or less probability that a response will be observed if that nutrient is applied, a low level implies a 50% or less probability, a medium level implies a 25% or less probability, and a high level implies that a response is not anticipated. Thus, one can see that a response to the application of a recommended nutrient is not guaranteed. The anticipated response is based on a probability calculated on a large number of soils and conditions which may or may not be representative of your soil. This discussion is not meant to diminish one's faith in using soil testing as a management tool for the health of one's turfgrass and environmental stewardship, but is to strengthen one's understanding of soil testing and subsequent recommendations.

Soil Analysis and Interpretation

One of the first steps in producing and maintaining beautiful turfgrass is to obtain an analysis of a representative soil sample from the turfgrass production area. The soil sample should be obtained by taking 15 to 20 small plugs at random over the entire area, and avoiding any areas with an unusual and/or identifying appearance. Ideally, one should sample the areas with special characteristics separately. Most turfgrass roots are located in the top 4 inches of soil, therefore, limit sampling depth to 4 inches.

Place the 15 to 20 plugs in a plastic container, mix them throughly, and send approximately one pint of the mixed sample to the UF/IFAS Extension Soil Testing Laboratory (ESTL) for chemical analysis. Your county Cooperative Extension Service can supply additional information on the proper technique of sampling and submitting a soil sample. The office address and phone number are listed in your local telephone directory, or you can contact the ESTL on the internet at soilslab.ifas.ufl.edu or by email at soilslab@ifas.ufl.edu.

A soil analysis supplies a wealth of information concerning the nutritional status of a soil and can detect potential problems that limit turfgrass growth. A routine soil analysis supplies information relative to soil acidity and the Mehlich-I (the chemical extractant currently used by the ESTL) extractable phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) status of the soil. A lime requirement determination is included in the routine analysis if the soil pH is below 6.0. Nitrogen (N) is not determined because, in most soils, N is highly mobile so its soil status varies greatly with rainfall and irrigation events. Nitrogen recommendations are based on the nutritional requirements of the turfgrass being grown, the region of the state, and the quality of the turfgrass desired.

As noted in Table 1, there is no interpretation made for soil test Ca or Fe. No interpretation is made for Mehlich-I extractable Ca levels because the extractant dissolves calcium compounds in the soil which may not be readily plant available. Thus, an erroneous interpretation of the plant-available Ca could be made. In most cases, Ca levels are adequate for turfgrass growth because Florida soils are inherently high in Ca, have a history of Ca fertilization, or receive Ca regularly through irrigation with high Ca water. The soil test level for Mehlich-I extractable Ca is used only to determine the type of limestone needed when lime is recommended. For most soils and crops, liming to ensure an adequate soil pH for proper growth will ensure more-than-adequate Ca. Research has shown no crop response to added Ca, from either liming materials or gypsum, when the Mehlich-I extractable Ca level is above 250 ppm.

The following levels of Mehlich-I extractable nutrients are considered adequate for optimum turfgrass growth.

The ESTL does not analyze for extractable Fe because definitive interpretation data are lacking. Significant correlation of soil test Fe levels and plant tissue levels is lacking and testing procedures tend to produce highly variable results. Most soils, except ones having a pH of greater than 7.0, generally contain adequate levels of Fe for optimum growth. Turfgrasses grown on soils with pH > 6.5 exhibit a greening response to Fe applied as a foliar spray. Unfortunately, reapplication may be required to sustain the desired color.

Liming recommendations are based on the Adam-Evans lime requirement test. This test is included in the routine soil analysis, but the test is only run if the soil pH is 6.0 or less. The quantity of

Table 1. Suggested Ranges for Mehlich-I Extractable Soil Nutrients Levels for Florida Turfgrasses

Macronutrients*			Micronutrients**		
P	K	Mg	Mn	Zn	Cu
ppm					
16-30	36-60	20-30	3-9	0.5-3	0.1-0.5

* Shown are defined as being the medium ranges of Mehlich-I extractable P, K, and Mg, in which cases a response to applied fertilization would be expected in 25% of the time or less.
** Soils testing below these levels of micronutrients are expected to respond to applied micronutrients. Interpretation of soil test micronutrient levels is based on soil pH. The smaller number is for soils with a pH of less than 6.0 and the larger number is for soils with a pH of 7.0 or greater. Mehlich-I extractable micronutrient levels are only determined when requested and require an additional charge.

lime recommended is based on the type of turfgrass being grown and the target pH desired.

Soil Acidity

Turfgrasses differ in their adaptability to soil acidity. For example, Centipedegrass and Bahiagrass grow better in an acid environment (pH 5.0 to 6.0) than St. Augustinegrass or Zoysiagrass, which grow best in near neutral or alkaline soils (pH 6.5 to 7.5) (Table 2).

leach more rapidly at pH values below 5.0 than in soils with reactions between 5.0 and 7.5. In certain soils, when the soil pH drops below 5.0 aluminum may become toxic to plant growth.

Normally, liming materials are used to increase soil pH and supply the essential nutrients Ca and Mg. The two most commonly available liming materials are calcic and dolomitic limes (Table 3). In instances where the soil tests low in Mg (less than 20 ppm Mehlich-I extractable Mg) dolomitic lime should be

Table 2. Desirable pH ranges for turfgrasses.

pH			
< 5.5	5.5 - 6.4	6.5 - 7.4	> 7.4
Bahiagrass	Bahiagrass	Bermudagrass	Bermudagrass
Bermudagrass	Bermudagrass	Fescuegrass	Italian Ryegrass
Carpetgrass	Carpetgrass	Italian Ryegrass	Paspalum
Centipedegrass	Centipedegrass	Paspalum	St Augustinegrass
	Italian Ryegrass	St Augustinegrass	Zoysiagrass
	Paspalum	Zoysiagrass	
	St Augustinegrass		
	Zoysiagrass		

Adjusting the Soil Reaction (pH)

Soil reaction, or pH, is important because it influences several soil factors that affect plant growth. Soil bacteria that transform and release N from organic matter function best in the pH range of 5.5 to 7.0; certain fertilizer materials also supply nutrients more efficiently in this range.

Plant nutrients, particularly P, K, Ca, Mg, B, Cu, Fe, Mn and Zn are generally more available to plants in the pH range of 5.5 to 6.5. These plant nutrients

adjust the application rate according to the calcium carbonate equivalents given in Table 3.

Table 3. Chemical composition and Calcium Carbonate equivalents of liming materials.

Materials	Chemical Composition	CCE*
Burned Lime	CaO	56
Hydrated Lime	$Ca(OH)_2$	74
Dolomitic Limestone	$CaCO_3$ $MgCO_3$	92
Calcic Limestone	$CaCO_3$	100

* The number of pounds of each material requred to neutralize the same quantity of acidity as pure calcium carbonate or calcic lime.

The amount of lime necessary to properly adjust the soil pH depends on the soil type. The greater the amount of organic matter or clay content of the soil and the lower the pH, the more lime required to increase the soil pH to a desired level. Soil lime requirement can not be determined by soil pH alone. If the soil pH is less than 6.0, a lime requirement test will be run on the soil sample to determine how much lime is required to increase the soil pH to 6.5. The lime requirement test is included in the routine standard analysis of a soil sample.

Soil Alkalinity

If a soil is too alkaline (i.e., has a pH of greater than 7.5) it must be determined whether the excess alkalinity is due to an inherent soil characteristic or previous excessive application of liming materials. Soils having a pH of greater than 8.3 are not alkaline due to the presence of calcium carbonate materials, because calcium carbonate has an equilibrium pH of 8.3 in water. Thus, excessively high soil pH is most likely due to the presence of elevated levels of sodium. It is difficult and uneconomical to change the pH of naturally occurring alkaline soils, such as those found in coastal areas or "fill soil" containing marl, shell, or limestone. If a high pH is due to applied lime or other alkaline additives, on the other hand, then acid-forming materials such as sulfur and ammonium sulfate can effectively reduce soil pH when applied at the proper rate and frequency.

Granular, super-fine dust, or wettable sulfur can be used to decrease soil pH. Granular sulfur is preferred on turfgrass production systems due to the ease of application (with cyclone fertilizer spreaders) and the reduced possibility of foliar burn from the granules. Throughly water-in sulfur after application, taking care to wash off all above ground turf parts. It takes approximately 1/3 the amount of sulfur to decrease the soil pH 1 unit as it does calcic lime to increase the soil pH 1 unit. Do not apply more than 10 pounds of sulfur per 1000 square feet per application. Repeat applications of sulfur should not be made more often than once every 30 days. Depending on the quantity of excess lime in the soil it may take several applications of sulfur to decrease the soil pH to the desired level. However, as stated above, if the soil is inherently high in pH due to the natural presence of lime the soil pH can not be reduced over a long period of time. It will gradually increase with time. If the soil has a naturally high calcium carbonate content, it would be more practical and much easier to change to a type of turfgrass that will tolerate high soil pH and not attempt to reduce the soil pH using a sulfur containing material. Sulfur oxidizes in the soil and reacts with water to form a strong acid (sulfuric acid) that can severely damage plant roots, so it must be used cautiously.

Tissue Analysis and Interpretation

While soil analysis may be influenced by a number of factors which can effect the desired response, tissue analysis is more exact and can specifically point to a given deficiency. Because of the mobility and chemical reactions involving most essential nutrients in soils precise levels that is plant available at any one moment is difficult to obtain through soil analysis. Soil analysis for some nutrients, because it is a snapshot of what is present at sampling time, does not always indicate their availability to plants. Tissue analysis offers a more precise estimate of the nutritional status at the time of sampling. Nutrient deficiencies can be detected with tissue analysis before visual symptoms appear. Tissue analysis may provide information on the relative health of the plant and interrelationships between essential macro- and micro- nutrients. When used in combination soil analysis can serve as a guide for the level of fertilization required to correct the deficiency and the tissue analysis can be used to indicate the specific nutrient deficiency and the level of that deficiency. Historical logs of tissue composition can be used to precisely calibrate a turfgrass fertilization program for optimum plant health and minimization of environmental impact. Tissue analysis, along with the visual appearance and soil analysis, can be used to diagnose deficiencies and improve the effectiveness of the fertilization program, especially for some micronutrients.

Tissue Sampling

Turfgrass clippings can be collected during regular mowing for tissue analysis. Clippings must be devoid of sand and fertilizer contamination. Clippings should not be collected immediately following fertilization, liming, top-dressing, pesticide application or any other cultural practice that results in contamination of the tissue sample. Collect tissue samples from an area that is free of weed or disease infestation. Place approximately a handful of well-mixed clippings in a paper bag. Do not use a plastic bag because, due to the lack of aeration, the tissue may begin to ferment prior to drying.

If there are drying facilities, place the collected clippings in a drying oven set at 70^o C (158^o F) for 24 hours and then mail to an analytical laboratory of your choice. The Extension Soil Testing Laboratory does not analyze bulk turfgrass tissue samples. If you do not have drying facilities, ship them, preferably overnight, to an analytical laboratory. Even if placed in a paper bag, if the sample is allowed to sit for more than a day the tissue will begin to ferment and the value of the tissue analysis will be lost.

Turfgrass that has recently been sprayed with micronutrients or pesticides should not be used for testing. Washing clippings to remove soil and dust particles is recommended prior to sending the samples to the lab for analysis. If you rinse one collection of clippings and not all, the nutritional analyses may not be comparable because the concentration of some nutrients, such as K, is mobile and a portion of the K may be removed during washing. Unwashed samples may appear to have a higher concentration than washed samples, and there may be a deficiency in the washed samples when, in fact, an adequate supply of K exists.

Interpretation of Tissue Analysis

Sufficiency levels of most essential nutrients in various turfgrass species do not vary greatly among the various species, except for N. In most cases a range in sufficiency levels for essential nutrients will cover all the various turfgrass species and cultivars. There are small differences in critical levels of essential elements for the different turfgrass species, which may become important when a very precise nutrient management program is desired because of environmental concerns. Highly precise critical tissue nutrient requirements are beyond the scope of this publication.

The sufficiency tissue N concentration can vary from a low of 1.5 percent for centipedegrass and bahiagrass to a high of 3.5 percent for cool-season overseeded ryegrass. The sufficiency ranges for tissue N concentration for the various turfgrasses are presented in Table 4. In most cases, tissue N concentrations below the minimum of the range would be deficient and above the range would be excessive.

The sufficiency tissue concentration of other macro- and micro-nutrients does not vary greatly among the turfgrass species and cultivars. The sufficiency ranges for most of the essential macro and micronutrients are presented in Table 5.

Table 4. Sufficiency ranges of tissue N concentration for selected lawn turfgrasses

	Bahia	Bermuda	Centipede	Paspalum	Rye	St. Augustine	Zoysia
N (%)	1.5-2.5	2.5-3.5	1.5-2.5	2.0-3.0	3.5-5.5	2.0-3.0	2.0-3.0

Table 5. Sufficiency ranges in turfgrass tissue concentration for selected macro- and micro-nutreints

P	K	Ca	Mg	Fe	Cu	Mn	Zm	B
----------------Percent (%)----------------				-------------------------ppm-------------------------				
0.15-0.5	1.0-3.0	0.5-1.0	0.2-0.5	50-250	5-30	25-100	20-250	5-20

These values represent the range over which a particular nutrient might vary across the various turfgrass species. They represent sufficiency ranges, which suggests that levels below the range may indicate a deficiency or above the range may represent excessive fertilization or toxicity.

The sufficiency ranges in the tables show the most current interpretation for nutrient concentrations in turfgrass tissue. If analytical test results are in the deficiency range or below the sufficiency range, an increase in fertilization for that nutrient may be required. A soil analysis for the element in question along with the soil pH can assist in making the determination in the rate of required fertilization. Alternatively, if tissue test results are above the sufficiency range, the fertilization program should be adjusted downward. If a change in fertilization is indicated, the adjustment should be reasonable. The intent is to find the correct nutrient management level that maintains turfgrass tissue nutrient concentration within the optimum range, but does not lead to over fertilization and possible adverse environmental and economic results.

General Fertilizer Recommendations

Fertilization is one of the key management practices in establishing and maintaining healthy, actively growing turfgrass. The desires of the individual lawn owner or turfgrass manager often dictate the level of fertility management. Due to environmental concerns, some think that less fertilization is always best, but research has shown that fewer nutrients are lost from the surface and leach through a healthy, well-maintained turfgrass than an unhealthy, sparsely established turfgrass.

A soil analysis furnishes information about the P, K, Ca and Mg status of the soil. Adjustments should be made in the fertilization and liming program to take advantage of the information derived from the soil test. A routine soil analysis does not include nitrogen (N), sulfur (S) or micronutrient analysis.

Nitrogen

Nitrogen is used in larger quantities than any of the other applied nutrients and needs to be applied on a regular basis to most turfgrasses grown in Florida lawns. The Florida Extension Soil Testing Laboratory does not analyze for soil N. Nitrogen is mobile in Floridaˇs sandy soils and correlations can not be established between analytical soil N and turfgrass response; therefore, N recommendations are based on the turfgrass N requirement. The actual quantity of N required depends on a number of factors: type of turfgrass being grown; turfgrass quality desired; type of soil and quantity of water the turfgrass receives, either through irrigation or natural rainfall; region of the state where turgrass is being grown; amount of shade under which the turfgrass is grown -- shaded turfgrass requires less N than does turfgrass grown in full sun; and disposition of clippings during mowing practices, (if clippings are discarded more N will be needed to sustain the same quality as if clippings were returned). Detailed N fertilizer recommendations for turfgrasses are available in Soil and Water Science Department Fact Sheet General Recommendations for Fertilization of Turfgrasses on Florida Soils, http://edis.ifas.ufl.edu/LH014.

Phosphorus

Phosphorus is used by turfgrasses in much smaller quantities than N, so much less P should be applied. Due to their marine origin, Florida soils often test high in Mehlich-I extractable P. Additionally, many of our soils have received abundant fertilizer P in the past, and have high soil test levels of P. Thus, many of our turfgrass soils do not require P for adequate turfgrass growth and survival. Nevertheless, the best way to know the P status of the soil is to test it.

Historically, phosphorus fertilizer sources were added to blended fertilizers as conditioners to aid in physical stability. However, due to recent changes as a result of the Urban Turf Rule, phosphorus is now limited in most of our turfgrass fertilizer materials. The Urban Turf Rule states that no more than 0.25 lbs of phosphate P (P_2O_5) per 1000 square feet may be applied per application and that no more than 0.5 lbs of phosphate P may be applied on an annual basis. A soil test for P should always be used to make decisions regarding P fertilization to limit the impact of fertilization. Additionally, the guidelines above should not be exceeded without a valid soil test showing a P deficiency.

As a general rule, P does not induce growth or color responses in turfgrass similar to N. In fact, research has shown that, in most cases, established turfgrasses respond very little to P application. Newly planted turfgrass areas are much more likely to respond to P application through enhanced rooting characteristics. The Urban Turf Rule provides an exception in P fertilization for newly planted turf or establishing turf in that a one time application of 1 pound of P_2O_5 per 1000 square feet can be made. A color response is seldom observed, except in deficiency situations where the soil is composed of uncoated (i.e., clean, white) sands which retain very little P. If the soil is an uncoated sand (pure white sand with no iron staining), P should be applied with caution because P tends to leach through these soils freely and can contaminate surface water bodies.

Potassium

Potassium is used in quantities by turfgrasses second only to N. As with P, however, turfgrasses do not exhibit growth and visible responses to K application in the same magnitude as do they in response to N application. Only when soil test levels are very low is there noticeable responses to K application. Levels of K application are often tied to the rate of N application and the disposition of clippings. Research has shown that turfgrass quality can be maintained with relatively low application rates of K on lawns where the clippings are returned during mowing. Maintaining a high quality turfgrass through high N fertilization requires more K for optimum growth and root production. One of the primary influences K has on turfgrass growth is the enhancement of rooting and tolerance to water, heat or cold stress.

Most Florida sandy soils contain low to very low levels of Mehlich-I extractable K. Medium-to-high levels of soil K are difficult to maintain in Floridaˇs sandy soils, so most turfgrass soils require K fertilization at some time during the year. The level and frequency of K application depends on the turfgrass being grown, the location in the state, the soil test level of K and the level of N being applied. Commonly the K fertilization rate is tied to the N fertilization rate. Thus, many turfgrass managers apply K at 50% to 100% of the N application rate. For additional insights to the K fertilization requirements of turfgrasses refer to Soil and Water Science Department Fact Sheet General Recommendations for Fertilization of Turfgrasses on Florida Soils, http://edis.ifas.ufl.edu/LH014.

Potassium is not considered a pollutant as are N and P, and precision in turfgrass K fertilization is not as demanding as in the case of N and P. Nevertheless, economics and attempts to avoid accumulation of excess salinity dictate soil testing for K and careful adherence to recommended K fertilization guidelines.

Micronutrients

Essential nutrients required in very small quantities for turfgrass growth are referred to as ˘micronutrientsˇ i.e., iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), chlorine (Cl), and molybdenum (Mo). Most low-maintenance turfgrasses do not require the addition of micronutrients but, if a micronutrient deficiency is suspected, the Extension Soil Testing Laboratory offers a soil test for Mn, Cu and Zn.

Interpretation of Mehlich-I extractable Mn, Cu and Zn depends of the soil pH. These micronutrients decline in solubility as the soil pH increases and plant availability may become limiting when the soil pH exceeds 7.0. The critical soil levels for these nutrients (i.e., the likelihood of a response to one or more of them) increase with soil pH for turfgrasses grown on acid sandy soil in Florida. The Mehlich-I extractant is not recommended for alkaline soils; micronutrient availability in the alkaline pH range is better evaluated with a tissue test or with a soil test extractant developed especially for alkaline soils.

Manganese

In most cases, a turfgrass response (greening) to applied Mn is likely if the soil pH is greater than pH 6.5. Soil tests and tissue analyses for Mn are more reliable in predicting a response than for Zn and Cu. Thus, if soil pH is high and turfgrass is not responding to macronutrient fertilization, a micronutrient soil test may be warranted. If the soil tests low or tissue analysis indicates a Mn deficiency application of 0.75 lbs of Mn per 1000 sq ft as manganese sulfate or manganous oxide is recommended. Turfgrasses growing on acidic soil, pH of 6.0 or less do not generally respond to a Mn application. Most irrigation water, whether deep well or effluent water, generally is high in pH due to the presence of Ca and/or Mg, and long term irrigation with these high pH waters may result in an elevated soil pH even though no lime is applied. For this reason most turfgrasses which have been maintained using high pH water will respond (green-up) in response to a Mn application.

Zinc

A turfgrass response to applied Zn has not been reported in Florida. Most responses to Zn application have occurred in tree crops, such as citrus and pecans. Bermudagrass did not respond positively to Zn application on soils testing low in Zn, nor did it respond negatively in soils testing high in Zn. This suggests that the apparent critical level for Zn is very low and that the toxicity level is very high. There appears to be very little reason to analyze for, or apply, Zn to turfgrasses grown on Florid soils.

Copper

In Florida, Cu deficiencies are generally confined to soils high in organic matter and to “new ground” just coming into cultivation in the flatwoods areas. Reported responses to Cu application on acid mineral soils is lacking. Turfgrasses produced for sod on organic soils often require an initial application of Cu, but a single application of Cu will suffice for four to five years. The application should not be repeated until soil or tissue tests indicate a need for Cu. Copper added to a soil is fixed and remains in the soil for a long time, and should not be added until a need is clearly identified because in many cases the threshold between an adequate level and an excess or toxic level of Cu can be relatively narrow. If Cu is required, application of 0.1 pounds of elemental Cu per 1000 square feet as either copper sulfate or finely ground copper oxide should supply the turfgrass needs for Cu for four to five years.

Iron

A strong relationship between extractable soil Fe, tissue levels of Fe and predictable responses to applied Fe does not exist, so the Extension Soil Testing Laboratory does not analyze for extractable Fe. However, there are certain soil conditions warranting consideration of an Fe application. In most Florida soils with a pH of 7.0 or greater, turfgrass greens in response to the application of Fe. Centipedegrass and Bahiagrass are particularly sensitive to Fe deficiencies and typically respond to Fe application when grown on soils with an alkaline pH. St. Augustinegrass and Bermudagrass growing on high pH soil will also respond to Fe application by greening. An Fe application is often used during the hot summer months to green the grass rather than applying additional N. Turfgrass Fe needs can be met variously. If the Fe deficiency occurs on acid soils, use one pound of iron sulfate per 1000 sqare ft. If the deficiency occurs on neutral or alkaline soils, use container recommended rate of an iron chelate. In many cases it is easier to correct an iron deficiency on high pH soils by making a foliar application of Fe. For this, spray 2 ounces of iron sulfate in 3 to 5 gallons per 1000 square feet. Responses to foliar applications are usually temporary, and frequent application (every 3 to 4 weeks) may be required.