ELEMENTAL SULFUR WITH IRON: KENTUCKY BLUEGRASS

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ABSTRACT

Iron (Fe) is known to improve greenness of Kentucky bluegrass (KBG; *Poa pratensis* L.), although applications are relatively costly and labor intensive. A new fertilizer material, elemental sulfur impregnated with Fe (ES-Fe), may provide an alternative source of Fe for KBG. The effects of ES-Fe on KBG was evaluated comparing 55 lb-Fe ac^{-1} ES-Fe to ferrous sulfate (FS) at the same rate and chelated Fe as a foliar (CF) or soil applied (CS) in a glasshouse study. A separate study evaluating increasing rates (55, 220, and 880 lb-Fe ac^{-1}) of ES-Fe on an alkaline and a calcareous soil either mixed with or applied to the surface of soil was also performed. The results of these studies show that uptake of Fe from FS was not different from the untreated control. However, uptake of Fe by KBG was enhanced with ES-Fe, CF, and CS. Uptake of Fe increased significantly with increasing rate of ES-Fe in a curvilinear response when mixed with soil and a linear response when surface applied. Although the data shows ES-Fe has potential as a replacement for the chelated sources, no impact on growth or greenness was observed over any treatment in these trials.

INTRODUCTION

Landscape managers spend substantial time and money maintaining aesthetically pleasing landscapes, of which turfgrass is an important component. In addition, athletic events conducted on natural grass playing fields are dependent upon having a healthy turfgrass that provides both cushioning and footing stability. A variety of construction and management factors combine to insure optimal field conditions, with nutrition being an important component.

Two nutrients primarily responsible for chlorophyll production, and therefore a lush, green turf are nitrogen (N) and iron (Fe) (Christians; 2007). Because N application often provides a rapid and highly visible greening, excessive amounts of this nutrient are often applied. Although this practice often provides good short term results, the long term impacts can be detrimental. Excess N leads to excessive shoot growth at the expense of root growth (Christians; 2007). Shallow roots lead to an unstable turfgrass surface, putting athletes and other users in danger of injury. In addition, excessive N application has the potential to degrade water quality (Rabalais et al.; 2002) and release nitrous oxide, which is a potent greenhouse gas (Isermann; 1994).

It has been reported that Fe applications may enable a reduction in N rates while simultaneously maintaining a green turf (Wehner et al., 1990; Yust et al., 1984). In addition to the benefits of a greener, more stable surface, this practice has the potential for reducing mowing and fertilization expenses.

Fertilizer containing Fe is readily available and commonly sold, but the effectiveness of these applications is questionable. Iron is an abundant component in the minerals that make up soil. This Fe is readily available to plants growing in acidic soils. The plant availability of Fe decreases dramatically as pH rises. Alkaline soils, including those in the arid and semi-arid regions of the western United States, have very low concentrations of plant available Fe. Plants growing in these soils have evolved mechanisms to increase Fe availability, but the addition of Fe fertilizer is sometimes necessary or, at least, beneficial.

However, Fe fertilization in alkaline soils is problematic due to the poor solubility of the Fe as it dissolves into soil solution and then precipitates out – rendering it very poorly available to plants. In order to overcome this solubility problem, chelated Fe is applied to soil and/or foliage, thus temporarily preventing Fe from reacting with the soil and increasing its assimilation into plants. Although this practice can be effective, chelated Fe requires monthly, if not weekly applications to be effective. This is costly and labor intensive.

A new Fe product, elemental sulfur (S) impregnated with Fe (ES-Fe) (Tiger-Sul Industries, Calgary, Alberta) may be an alternative to chelated Fe fertilizers. Elemental S oxidizes slowly to form sulfuric acid, thus lowering the soil pH immediately around the fertilizer pastille. This serves as a slow release form of S, which is another essential nutrient for plants. In addition, the plant availability of Fe and other nutrients (phosphorus, zinc, manganese, and copper) known to have adverse solubility issues at high pH is improved in the immediate area around the pastille.

OBJECTIVES

The effects of ES-Fe material on KBG were evaluated in two glasshouse studies: 1) comparing ES-Fe to traditionally accepted Fe products and 2) evaluating increasing rates of ES-Fe on an alkaline and a calcareous soil either mixed with or applied to the surface of soil.

MATERIALS AND METHODS

Two KBG Fe studies were conducted in a glasshouse. Five replications of each treatment were arranged in a randomized complete block design (RCBD). Soils (~1.5 lb) were placed in a cylinder at a common and uniform bulk density and a uniform height (9 inch) of soil.

For the Fe Source study, five Fe treatments (Table 1) were applied to two KBG cultivars, Everest (E) and Limousine (L). The ES-Fe fertilizer (Tiger 55% S 22% Fe, Tiger-Sul Products, Calgary, Alberta). The ES-Fe and FS were mixed with the top inch of soil immediately prior to planting. The CS treatment was split applied as a 50 ml soil drench every 28 days for a total of four applications. The CF treatment was split applied as a 2 ml spray every 28 days for a total of four applications. The cultivars were grown in a sandy loam constructed soil with the following properties: pH 7.2, 0.31% $CaCO_3$, and 21 mg kg^{-1} DTPA extractable Fe. For the Rate study, ES-Fe was applied to two soils (Tables 2 and 3) and planted with the Limousine cultivar. The ES-Fe was mixed with the top 1 inch of soil immediately prior to planting. Sulfur was balanced across all pots for both studies, including the untreated control with elemental S.

Table 1. Treatments for Iron Source study applied to two separate KBG cultivars.

	Iron Source and Application Method		Fe Rate, lb ac^{-1}
1	Untreated Control	U	0
2	Elemental S impregnated with Fe – Soil Applied	ES-Fe	55
3	Ferrous Sulfate – Soil Applied	FS	55
4	Fe Chelate (6% EDDHA) – Soil Applied	CS	55
5	Fe Chelate (6% EDDHA) – Foliar Applied	CF	5.5

Mostly normal soil moisture cycles were followed by allowing the soil to dry down to a point just before or at water stress for the KBG. However, the effects on Fe nutrition as a function of excessive soil moisture (increased frequency of irrigating to avoid soil dry down) were evaluated towards the end of the trial when no Fe deficiency was observed under the normal irrigation practices.

Table 2. Selected soil properties for two soils used in for an Fe Rate study for Kentucky bluegrass grown in a glasshouse. Soils were collected from Bingham county, Idaho, USA.

Soil	pH	CaCO3, %	DTPA Fe, ppm	Extractable S, ppm
Escalante sandy loam	8.2	2.0	3.1	35
Quincy sand	7.8	0.1	5.1	25

Table 3. Treatment structure an Fe Rate study for Kentucky bluegrass grown in a glasshouse.

	Soil	Application Method	Fe Rate, lb ac^{-1}
1	calcareous loam (Escalante)	N/A	0
2		Surface	55
3			220
4			880
5		Incorporated	55
6			220
7			880
8	alkaline sand (Quincy)	N/A	0
9		Surface	55
10			220
11			880
12		Incorporated	55
13			220
14			880

Similarly, the effects of varying nitrogen (N) nutrition were evaluated over the course of the trial in an effort to force Fe deficiency symptoms to appear. Initially, N availability was relatively high with addition of polymer coated urea (Duration® CR Type II, Agrium Advanced Technologies, Brantford, Ontario, Canada) for a total rate of 220 lb N ac^{-1}. Slight N deficiency was observed after approximately 60 days and this condition was allowed to persist for 20 days, followed by application of a moderate amount of N (287 lb ac^{-1}).

Fifty days after planting, the KBG continued to show no visual signs of Fe chlorosis. In an attempt to induce Fe deficiency, calcium carbonate ($CaCO_3$) was added to the irrigation water (200 ppm). Again, no Fe chlorosis was observed. Ninety days following planting, $CaCO_3$ was added and mixed with the soil at a 1% concentration. This effectively converted the slightly alkaline soil to a calcareous soil with a pH of approximately 8, which would be a worst-case scenario for Fe solubility and plant availability.

Turf clippings (2.5 inch) were taken twice weekly starting at 23 days after planting and removed for drying and weighing. Visual ratings for color were taken periodically. Chlorophyll content was estimated using a chlorophyll content monitor (CCM-200, Opti-Sciences, Hudson, New Hampshire). At 178 days after planting, shoots and roots were harvested separately by cutting at the crown and gently removing and washing roots from the soil. Rooting depth was measured prior to removal. Shoot height and clipping length were measured periodically and at harvest. Total tissue yields and moisture content were also measured and analyzed. Shoot and root tissue were analyzed for nutrient content by inductively coupled plasma (ICP, Thermo Electron Corporation, Franklin, Maryland) spectroscopy. Results were statistically analyzed with SAS using ANOVA with Duncan mean separation test.

RESULTS AND DISCUSSION

Iron Source

Cultivar and the interaction between cultivar and iron source did not result in significant differences in this trial, indicating that the response to the various Fe sources were similar for both cultivars. Furthermore, it was found that Fe source did not impact most of the measured parameters, including: overall visual condition, visual color ratings, shoot height, clipping yield, shoot/root dry matter at harvest, and root depth at harvest, root nutrient concentrations, and shoot concentrations for most nutrients (data not shown). The only significant impact for Fe source was shoot Fe concentrations (*Pr* > F 0.0023; Figure 1). The Fe concentrations in the shoots of both cultivars increased over the untreated control for all treatments except FS.

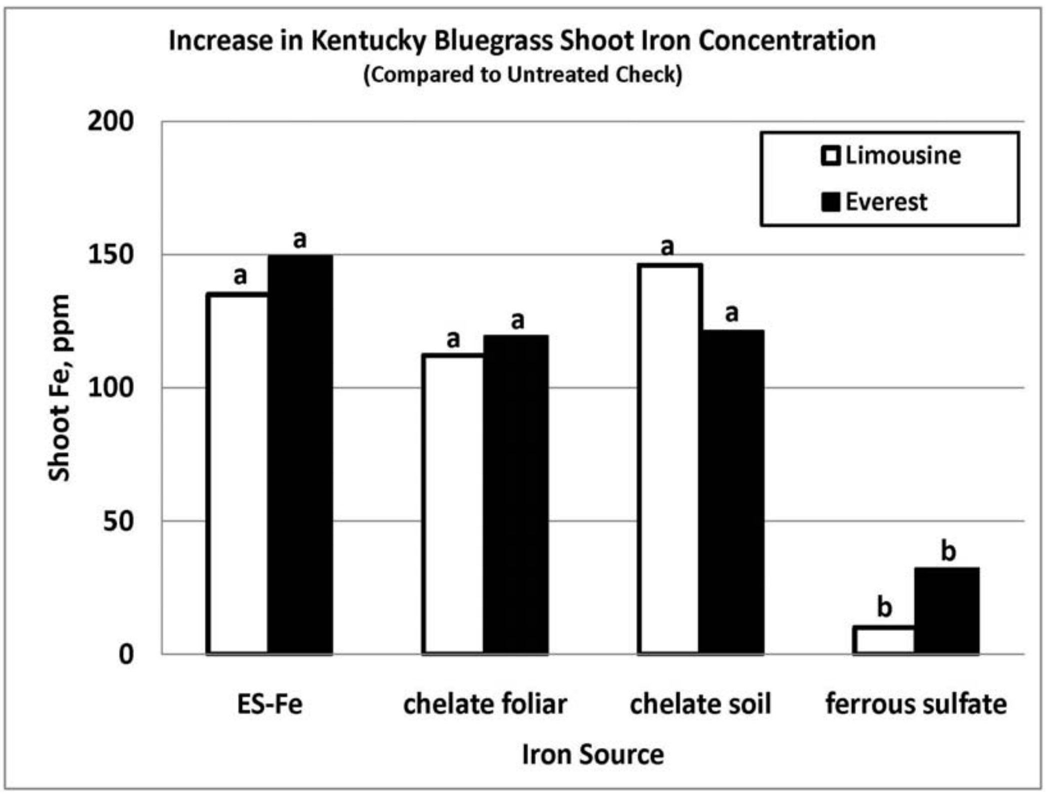

Figure 1. Increase in shoot Fe concentration over an untreated check for four Fe fertilizer sources applied to two KBG cultivars. Bars with the same letters indicate that there was no statistical difference between treatments.

The lack of shoot Fe concentration increase for FS shows it is not an effective Fe source for plants when incorporated into the soil profile. This is not surprising as it is known that Fe is very insoluble at alkaline pH and, unlike the other treatments, the FS did not have any mechanism to prevent the Fe from reacting with hydroxide and other anions to form poorly soluble mineral precipitates. It was known that the CS and CF treatments would be effective due to the ability of turfgrass to utilize EDDHA chelated Fe sources and, indeed, these sources resulted in increased Fe in shoots. Similarly, the ES-Fe treatment increased Fe in the shoots and, as such, shows that this source of Fe is a likely substitute for chelated Fe sources when an increase in Fe is needed.

Rate

There were not significant differences for soil type or the interaction between soil type and rate of application, indicating that the response to ES-Fe was similar in both soil types at all rates and methods of application. Furthermore, it was found that the rate of ES-Fe, method of application, and their potential interactions did not impact most of the measured parameters previously identified (data not shown). The only parameter that had a significant impact was the rate and method of application response for shoot Fe (Pr > F 0.0011; Figure 2) and S concentrations (data not shown). Not surprisingly, the Fe and S concentrations in the shoots increased as rate of ES-Fe increased, especially when surface applied.

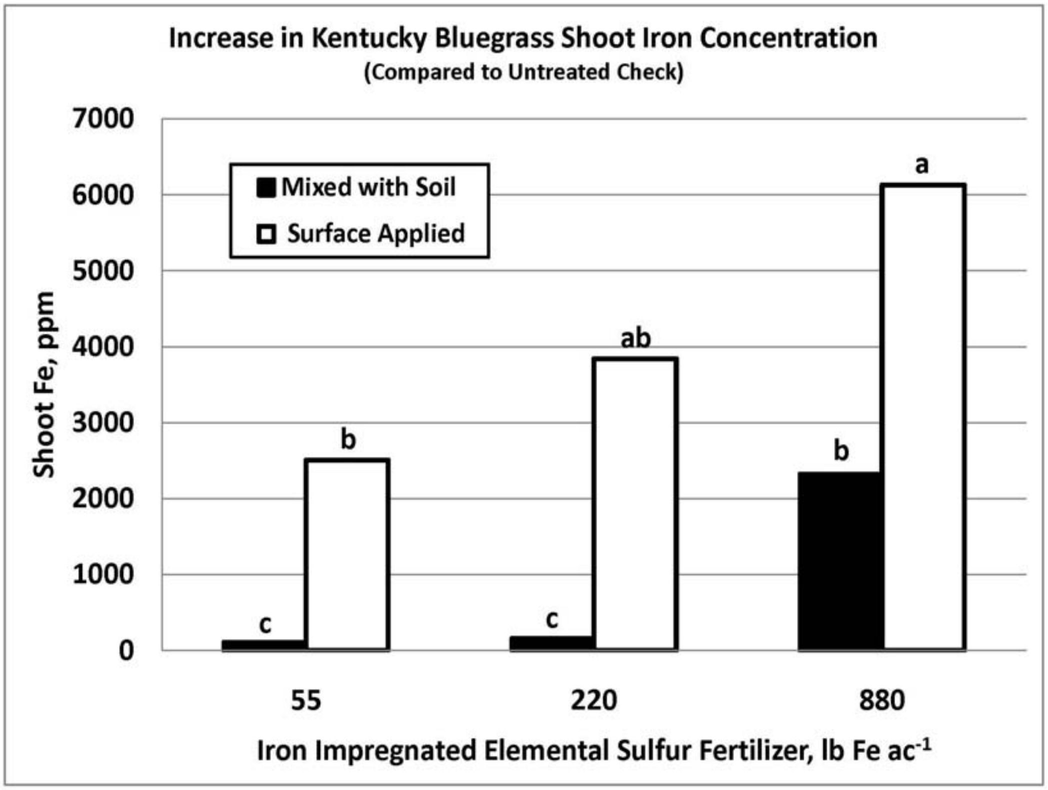

Figure 2. Increase in shoot Fe concentration over an untreated check for three rates of ES-Fe fertilizer either surface applied or incorporated into the soil. Bars with the same letters indicate that there was no statistical difference between treatments.

The reasons why the surface application had a greater impact on shoot nutrient concentration are likely related to rooting efficiency for S and both rooting efficiency and soil chemistry for Fe.

Turfgrass cultivars are especially effective at surface feeding due to a majority of roots being found in the top inch of soil. In this experiment, roots only reached depths of 5-8 cm (2-3 inches), but the ES-Fe was mixed to the full depth of soil in the containers. Therefore, some of the fertilizer did not come into contact with the roots for the incorporated treatments.

Furthermore, the ES-Fe on the surface was more highly concentrated and, therefore, would be expected to maintain the Fe in a more soluble form; in comparison to mixing the fertilizer into the soil where it would be less soluble due to both lower concentration of Fe and higher pH (acidification would be expected to be greater as fertilizer pastilles come into close proximity for the surface applied treatments). With regards to the surface application, there was a linear response with Fe uptake in the plant with an increased rate in the ES-Fe. With the mixed treatment, there was a curvilinear response for Fe to the rates of application. This is likely due to the impacts of soil chemistry discussed above, with the effect of pH solubilization of Fe not making much impact until the highest rate of Fe was applied.

SUMMARY

These results show that KBG effectively took up Fe from elemental sulfur impregnated with Fe (ES-Fe) as well as soil and foliarly applied chelated Fe. Although the data shows ES-Fe has potential as a replacement for the chelated sources, no impact on growth or greenness was observed over any treatment in these trials.

The alkaline soil selected for use in this trial is prone to produce plants that suffer from Fe chlorosis stress (based on results with dry beans and other species) and it was expected that chlorosis would develop with KBG. However, chlorosis did not develop in these trials.

Efforts were made to induce chlorosis through varying soil moisture, as well as evaluating under a range of N fertility conditions. When no signs of chlorosis appeared, additional efforts were made to create a worst case scenario for Fe availability through the addition of additional $CaCO_3$ to the irrigation water and, later, to the soil profile. Chlorosis never developed in the plants in this trial and greenness was not enhanced by any of the Fe treatments applied, even though all of the Fe treatments except $FeSO_4$ increased Fe concentration in the plant shoots. In fact, Fe treatments did not impact any measured growth parameter other than Fe concentration in shoots.

These results are surprising in light of previous studies that have shown improvements in the color of KBG with Fe application and, as such, suggest that intensive breeding programs have resulted in KBG cultivars that are not susceptible to Fe chlorosis stress. These results have been confirmed with hydroponic, glasshouse, and field studies with several different KBG cultivars (data not shown). Therefore, Fe application should not be included as part of a regular fertilizer program unless Fe chlorosis is confirmed. If Fe chlorosis is confirmed, ES-Fe is a viable alternative to expensive and/or labor-intensive Fe chelates.

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