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Thatch Accumulation in Tall Fescue Varieties

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While taking soil cores to measure tall fescue rooting depth, a significant amount of thatch build-up was observed. This was surprising since tall fescue does not usually accumulate much thatch in southern California and thatch control has never been a management concern with this species. To determine if thatch accumulation could be a potential management concern with the new turf-type tall fescue varieties, the 39 varieties present in the National Variety Trial at the UC Riverside turf plots were sampled.

The three year old National Variety Trial was designed as a randomized complete block with three replicates. The turf was mowed weekly at a 2 in. height. Irrigation was on an as needed basis and the plot was fertilized every six weeks with 1 lb. of actual nitrogen per 1000 sq. ft. On March 3, 1987, one plug, 2 in. in diameter, was taken from each replicate of each variety and the thatch was measured. Also, the leaf texture of all replicates was visually rated on a 1 to 9 scale (1 = coarse, 9 = fine).

Thatch was present in all varieties ranging in thickness from 0.64 to 1.14 in. Generally, the pasture-type varieties developed the least thatch while the newer turf-types, including dwarf varieties, accumulated the most.

Analysis of variance indicated highly significant differences in thatch thickness between varieties. Cluster analysis produced two significantly different groups as can be seen in Table 1.

Turf texture also differed significantly between varieties ranging from 4.0 to 7.7. Cluster analysis produced four groups of varieties based on texture (Table 2). The coarsest grouping consisted primarily of forage-types while the first generation turf-types were somewhat finer in leaf texture. Second generation turf-type and dwarf varieties dominated the finest textured grouping.

Thatch thickness and turf texture were positively correlated ($r = 0.723$), supporting the hypothesis that the new, finer textured tall fescue varieties tend to accumulate more thatch than the older forage varieties.

Due to limited sampling and data variability, this study is not considered to be conclusive. It does, however, point out a trend in tall fescue thatch accumulation that deserves further examination. A new National Variety Trial, scheduled to be established in the fall of 1987, will be evaluated over a number of years.

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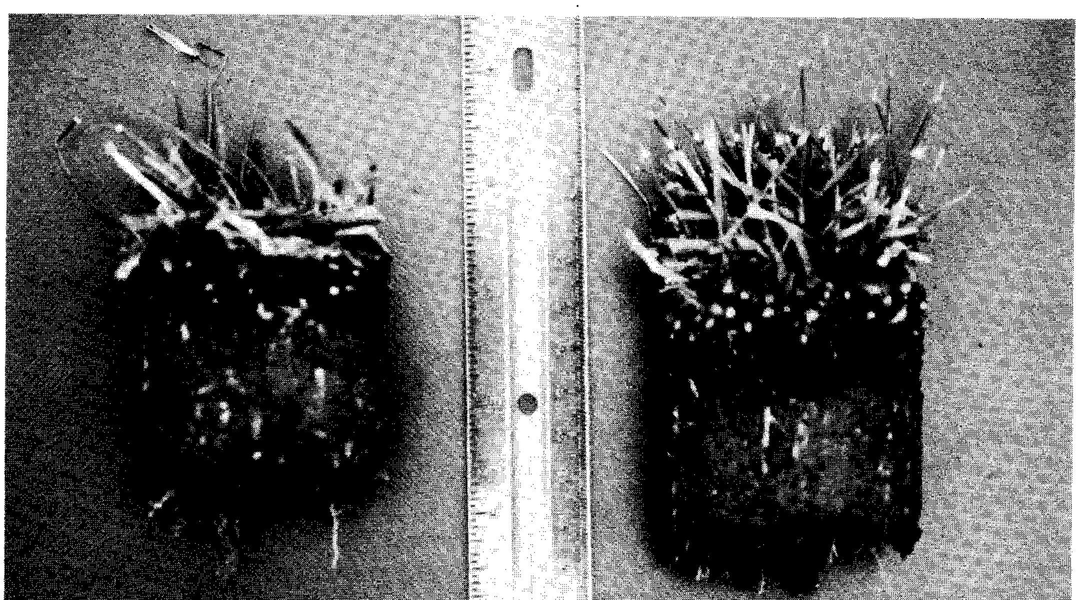

'Alta', a forage-type tall fescue (left) and 'Mojave', a turf-type variety. Note the difference in thatch thickness and shoot density.

Table 1. Cluster Analysis Grouping of Tall Fescue Varieties by Thatch Thickness.

Group I variety	Thatch in.	Thatch mm
KY-31	0.64	16.3
KS 78-4	0.67	17.0
579	0.67	17.0
NK 81425	0.70	17.7
NK 82508	0.70	17.7
Clemfine	0.72	18.3
Johns tone	0.77	19.7
Pacer	0.79	20.0
Falcon	0.79	20.0
Maverick	0.79	20.0
Brookston	0.81	20.7
562	0.81	20.7
Finelawn	0.83	21.0
Festorina	0.83	21.0
MER FA 83-l	0.84	21.3
Willamette	0.87	22.0
Bonanza	0.87	22.0
Mustang	0.88	22.3
Jaguar	0.88	22.3
Barcell	0.89	22.7
5M4	0.89	22.7
OL2	0.89	22.7

Group II Variety	Thatch in.	Thatch mm
Houndog	0.92	23.3
Rebel	0.93	23.7
0lymplc	0.93	23.7
SYN-GA-1	0.94	24.0
Tempo	0.97	24.7
Apache	0.98	25.0
5D3	0.98	25.0
Rebel II	1.00	25.3
Arid	1.01	25.7
Trident	1.02	26.0
5DW	1.02	26.0
Adventure	1.04	26.3
Unknown	1.04	26.3
51w	1.12	28.3
Mojave	1.12	28.3
Trailblazer	1.14	29.0

Table 2. Cluster Analysis Grouping of Tall Fescue Varieties by Leaf Texture.

Group I Variety	Texture Rating
Johns tone	4.0
KY-3 1	4.0
KS 78-4	4.0
NK 81425	4.0
Clemflne	4.7
579	4.7

Group II Variety	Texture Rating
NK 82508	5.0
Festorina	5.0
MER FA 83-l	5.3
Pacer	5.3
Houndog	5.3
Brookston	5.3
Finelawn	5.3
SYN-GA-1	5.3
Tempo	5.3
Barcell	5.3
Willamette	5.7
5GL	5.7
Arid	5.7
562	5.7

Group III Variety	Texture Rating
Rebel	6.0
Falcon	6.0
Maverick	6.0
Mustang	6.0
Olympic	6.0
Bonanza	6.0
Unknown	6.0
Mojave	6.0
OL2	6.0
Trident	6.3
Apache	6.3

Group IV Variety	Texture Rating
Adventure	6.7
Rebel II	6.7
5M4	6.7
51w	7.0
5DW	7.0
Jaguar	7.3
fD3	7.3
Trailblazer	7.7

Iron and Turf Culture

Ali Harivandi[1]

Introduction

Success in turfgrass management is measured not by total “matter” production but primarily by appearance. Anything short of a rich, deep green turfgrass may be undesirable. The darkness of turf green is directly related to the chlorophyll content of the shoot; yellowing of turfgrasses reflects reduced chlorophyll content in the leaves. Although genetic makeup of a given turfgrass specie or variety plays a major role in chlorophyll production, nutritional dericiences, especially those of nitrogen (N) and iron (Fe), are usually responsible for lower chlorophyll production.

Turfgrass managers universally recognize the importance of N in a successful management program and apply large quantities of it. The role of iron in turfgrass management, however, is not as widely recognized as that of N and, therefore, Fe is not as widely utilized in turfgrass management.

IDENTIFYING TURFGRASS IRON DEFICIENCY SYMPTOMS

Iron chlorosis in turf appears first in newly developed leaves which turn light green and then yellow, while older leaves remain green. An entire plant turns yellow from lack of Fe only after a prolonged deficiency. Leaves yellow interveinly with veins remaining green unless the Fe deficiency is very severe or prolonged. Growth of Fe-deficient turf, despite chlorotic leaves, remains normal. An available Fe shortage acute enough to produce a bleached, almost white turf produces few morphological changes, with only an occasional necrotic spot at leaf margins or tips. If severe Fe deficiency continues for too long, turfgrass will die. Iron chlorosis is not uniform over an entire area but appears in randomly scattered spots, creating a mottled appearance. This mottling, typical of Fe deficiency, is an aid in distinguishing between Fe and N deficiency, the latter causing uniform yellowing over a large turf area.

Frequent and close mowing of the turf tends to intensify Fe deficiency symptoms. Application of N fertilizers may also intensify the symptoms. Turf species and cultivars vary in their Fe absorption efficiency; thus, at uniform soil Fe contents, some grasses may absorb enough iron to satisfy their needs while others exhibit chlorosis. In most cases, [e.g. Kentucky bluegrass *(Poa pratensis* L.)], however, a soil-available Fe content greater than 20 ppm should be adequate (2). If Fe chlorosis persists in a soil known to contain generally adequate supplies of available Fe, plants can be tissue-tested for chlorophyll and/or Fe. Table 1 provides leaf Fe and chlorophyll contents for 25 Kentucky bluegrass cultivars and blends grown at soil-available iron of 13.5ppm and pH of 7.3 (7). The variability in green color of these grasses illustrates the effect of genetic variability on Fe requirements; the actual numbers may suggest the kind of range within which soil Fe has to be adjusted. The data from Table 1 suggest that in order to produce an acceptable green color, Kentucky bluegrass dry shoot tissue should contain more than 177ppm of Fe and/or 2.33 mg/g of chlorophyll. A previous study (12), in which leaf Fe contents were measured in Kentucky bluegrass and Bermudagrass *(Cynodon spp.)* grown in nutrient solutions, concluded that chlorotic leaves can be expected at leaf Fe contents of less than 50-70 ppm.

Although Fe deficiency symptoms may appear throughout the growing season, they usually are most severe late summer to mid-fall. This may be due to discrepancies in soil and air temperatures which results in faster shoot than root growth. In the latter situation it is probable that chlorosis develops because Fe absorption is not sufficient to support the rapidly growing turf shoots.

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CAUSES OF TURFGRASS IRON DEFICIENCY

Any one (or a combination of several) of the following may be the cause of Fe deficiency symptoms in turfgrasses:

a. **Deficiency of iron in the soil.** Where soil has been modified as a growing medium (e.g., sand golf and bowling greens and athletic fields, etc.), high leaching and low cation exchange capacity (CEC) may result in Fe deficiency.

b. **Poor root system or weak stand of grass.** A poor root system is not efficient in absorbing Fe, and, if in addition to having a poor root system a turf stand is growing on inherently low-available Fe soil or is itself an Fe deficient species/cultivar, it is likely to develop Fe chlorosis. The most common causes of poor root systems are: scalping; excessive removal of thatch; damage by root and crown diseases, root-feeding insects or nematodes; water-logging (over-irrigation or lack of drainage); and compaction.

c. **Antagonisms from other trace elements.** Elements such as copper (Cu) may compete with Fe for plant absorption thus causing chlorosis in certain soils (8). This need not concern most turf managers since the phenomenon is relatively rare in turf management. However, use of treated sewage effluent water for turf irrigation or sewage sludge as a soil amendment may lead to Fe chlorosis through competition from other heavy metals.

d. **Excess Nitrogen fertilization.** Heavy N application, particularly when shoot growth rate exceeds that of roots, may induce or accentuate Fe chlorosis. In general, N should never be applied at higher than recommended rates nor be applied during mid to late summer when high temperature may retard turfgrass root growth in favor of excessive shoot growth.

Table 1. Shoot Iron, Chlorophyll content and Color Ratings of Kentucky Bluegrass Cultivara and Blends. (1 = light yellow, 10 = dark green).

Cultivar or blend	Color rating	Chlorophyll (mg/g)	Total plant Fe (PPm)
Adelphi	10	2.27	271
Ill	10	3.56	296
Sodco	10	3.20	273
Sydsport	10	2.90	266
Windsor	10	2.93	268
Fylking	9	2.88	270
Newport	9	2.62	224
Prato	9	2.75	250
Baron	8	2.53	233
Code 95	8	2.63	224
Common #1	8	2.60	236
Delta	8	2.73	248
Geary	8	2.69	246
Kenblue	8	2.69	262
Pennstar	8	2.54	203
Common #2	7	2.55	226
Melle	7	2.45	211
Primp	7	2.42	183
s 21	7	2.27	202
Merion	6	2.33	177
Warren's A-20	5	2.16	172
Park	4	2.08	198
Arboretum	3	2.07	164
Nugget	2	1.53	165
Warren's A-34	2	1.68	155
Common + Kenblue	10	3.65	275
Windsor + Merioa	10	2.72	262
Meriod + Delta	7	2.31	176
Fylking + Penostar + Nugget	5	2.17	175
Park + Delta + Newport	3	1.74	171
Mean	7.3	2.47	222
L.S.D. (1% level)		1.50	116

Each value is a mean of 3 replicates.
Adapted from: Harivandi and Butler, 1980.

e. **High soil phosphorus content.** Soils containing relatively large quantities of phosphorus (P), either naturally or after heavy P fertilization, are particularly conducive to Fe chlorosis in certain plants, including turfgrasses. It has been suggested that at low soil pH's, P combines with Fe to produce insoluble (i.e., unavailable) iron phosphate (8). At high soil pH, an abundance of soil P may cause P accumulation inside the plant sufficient to inactivate a portion of the absorbed Fe within the plant and thus induce or accentuate chlorosis (1).

f. **Bicarbonate in irrigation water.** More recently, emphasis has been placed on the effect of bicarbonate ion (HCO) on Fe chlorosis. This is primarily due to the use of reclaimed water for turf irrigation, some of which contains high levels of bicarbonate. By raising the pH of the root zone, the bicarbonate ion may favor Fe precipitation (as iron hydroxide), resulting in Fe deficiency.

g. **High soil pH ("Lime-Induced Chlorosis").** Iron deficiency in turf-grasses occurs most often in alkaline calcareous soils (lime-induced chlorosis). In general, at soil pH's of 7 and below, Fe availability is favorable to turfgrass. At pH's higher than 7 (typical of calcareous soils), Fe availability declines dramatically and can limit turf health.

h. **Turf susceptibility to iron deficiency.** Iron chlorosis may affect both cool and warm season turfgrasses. Iron chlorosis has been observed in Kentucky bluegrass, perennial ryegrass *(Lolium perenne L.),* fine fescues *(Festuca spp.)* Bahiagrass *(Paspalum notatum flugge.),* centipedegrass [Eremochloa ophiuroides (Munro.) Hack.], zoysiagrass *(Zoysia spp.),* St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze], Creeping bentgrass *(Agrostis palustris Huds.),* annual bluegrass *(Poa annua L.),* tall fescue *(Festuca arundinacea schreb.)* and bermudagrass. Among the cultivars of each species, a dramatic range of responses to Fe chlorosis may be observed. This range reflects a wide variation in the cultivars' ability to absorb and/or utilize Fe. Table 1 presents color responses of top performing Kentucky bluegrass cultivars and blends in relation to the Fe content of the leaves. Table 2 contains results of similar research on bermudagrass (10). Overall, it appears that within each species some cultivars are more efficient in Fe absorption and utilization than others.

Table 2. Color Ratings of Bermudagrass Cultivars Grown in Soil Low in Available Fe.

Cultivar	Color Ratings*
Tifway	7.7
Tif green	7.5
Royal Cape	7.3
Midiron	7.3
Ormond	7.3
Santa Ana	7.1
Texturf	7.0
Pee Dee	7.0
Algonquin	6.7
Wes twood	6.5
Tufcote	6.4
St. Joseph	6.4
L.S..D. PO.01	0.13

Adapted From: McCaslIne, Samson and Baltensperger. 1981.

CORRECTING TURFGRASS IRON DEFICIENCY CHLOROSIS

Once the cause(s) of Fe chlorosis is determined, one or more of the following practices may be investigated as a remedy:

a. **Correct causes of poor root system and weak turf.** If Fe chlorosis develops between a pH of 5 and 7, a further examination of the turf root system is appropriate. Short, stubby, dark roots indicate a poor root system that is unable to extract adequate iron or other nutrients. As mentioned above, possible causes of a poor root system include lack of drainage, over irrigation, compaction, disease, insect and nematode damage. Once the cause of weak roots is remedied, Fe deficiency symptoms usually disappear.

b. **Follow a proper nitrogen fertilization program.**

c. **Analyze the soil for phosphorus.** Do not add P unless soil tests call for it. It is also advisable to reduce P fertilization in cases of recurring Fe chlorosis.

d. **Check irrigation water for bicarbonate content.** Where Fe deficiency is a recurring problem, water with high bicarbonate should not be used. If it is not possible to correct the water content, fertilizing with Fe will be essential. Applying elemental sulfur on a regular basis to lower pH and reduce the impact of bicarbonate may be helpful in some cases.

e. **Use iron-efficient turfgrass species / cultivars.**

f. **Reduce pH.** As mentioned earlier, the most widespread cause of Fe deficiency is Fe unavailability to plants with a high soil pH. Often, therefore, a relatively easy way to correct iron deficiency is to lower the soil pH. This is usually accomplished on calcareous soils by application of elemental sulfur. At a pH above 7, sulfur application over a long period may reduce Fe deficiency. However, calcareous soils of arid and semi-arid regions have a high buffering capacity and, therefore, require relatively large quantities of sulfur over an extended period to lower their pH. Whether applied as a spray or in dry form, sulfur must be washed into the soil immediately to prevent shoot burning. It is a good practice to apply it after aerification to assure better infiltration into the soil and thus more rapid effects. If a rapid correction of Fe deficiency is desired on these soils, fertilizers containing Fe should be applied.

An investigation into the use of sulfuric acid to lower the pH of calcareous soils on which common bermudagrass grew [cynodon dactylon (L.) Pers.] demonstrated that this form of sulfur was more effective than either ferrous sulfate or iron chelate (Fe-EDDHA) in correcting Fe chlorosis (13). The greenhouse study varied rates and times of sulfuric acid application to bermudagrass grown on calcareous soil (pH of 8-8.3) in pots. It then compared treatments for plant growth and chlorophyll concentration. The superiority of the sulfuric acid treatment was explained as an increase of Fe availability in the soil. The researchers concluded that sulfuric acid may be easily and effectively added to the surface of chlorosis-prone, calcareous soils prior to turf establishment. The acid treatment should be followed by leaching, however, to remove salts produced by acidification. Results of this study also suggest that irrigating chlorotic bermudagrass grown on calcareous soil with water containing up to 3% sulfuric acid is likely to stimulate growth and greenness. The researchers caution, however, that discrepancies between greenhouse and field studies should be considered. In the field, for example, responses to treatment may be altered by other management practices such as more frequent mowing than employed in the greenhouse study (13).

Where pH is only slightly above the desirable range, regular application of an acid forming nitrogen fertilizer (e.g. ammonium sulfate) will help keep pH in check. It is important to monitor soil pH closely when acid-forming materials are used over long periods, since a harmful acid condition may develop in some soils by repeated use of acid-forming fertilizers.

g. **Apply iron containing fertilizers.** Application of Fe containing fertilizers is appropriate where rapid improvement of turf is desired. Several commercial Fe containing materials are available for use on turfgrasses. These include soluble sources (ferrous sulfate, ferrous ammonium sulfate), synthetic chelated carriers (Sequesterene 138 and 330, Ferriplex, Rayplex), natural chelated iron from sewage sludge, and mined iron containing minerals (Acid Iron, Iron-Sul). The amount and kind of Fe needed to correct chlorosis depends on its serverity, time of year, whether or not the material will be sprayed on or applied as granular, etc. In addition to fertilizers mentioned here, many regularly available brands of complete turf fertilizers contain various amounts of Fe. Under severe Fe deficiency conditions, however, the low percentage of Fe common to most complete fertilizers is not sufficient.

That source and amount of Fe applied, as well as the time and method of application, influence results as demonstrated by the following three studies.

Minner and Butler (11) of Colorado State University compared various rates of common Fe containing fertilizers for their residual effect on turf quality and plant Fe and chlorophyll content. Table 3 lists fertilizers used in this study and summarized results. Materials from all three categories used (chelates, iron salts, and acid-treated mine tailings) increased greening of Kentucky bluegrass 17 days after application. After 384 days, grass treated with Fe salts and acid mine tailings was significantly darker green than grass treated with chelates. The latter, in fact, produced an unacceptable color similar to untreated grass.

The same reseachers (11) also reported a positive linear response to ferrous sulfate by Kentucky bluegrass up to a rate of 48 kg Fe hectare. There was no further increase in color above this rate and the lowest rate to achieve acceptable color was 27 kg iron/hectare.

Work at New Mexico State University (9) evaluated the effect of several Fe containing materials on Fe chlorosis of common bermudagrass. Two weeks after the application, researchers conducting this experiment noted similar significantly positive results from three different treatments: iron chelate (Fe-EDDHA), at 2.6 lb elemental Fe/acre, zinc and Fe chelate (Zn + Fe-EDDHA) at 6.2 lb elemental zinc and 2.6 lb elemental Fe/acre, and a spray application of ferrous ammonium sulphate (FAS), at the rate of 2.6 lb of elemental Fe/acre. Four weeks after application of materials, the effect of FAS had lessened while the greening effects of Fe chelate remained. Six and a half weeks after application, only the greening effects of iron plus zinc chelates were still visible. The bermudagrass was again sprayed with iron just prior to dormancy to determine whether the effect of supplemental Fe could be carried over to the following spring. No differences in color were observed the following spring, however, between Fe-treated and check plots. The grass of all plots was equally chlorotic at this time;

a spray application of ferrous sulphate eliminated the chlorosis within one week. Thus, to be effective, liquid Fe fertilizer should be sprayed only during nondormant periods (9).

Unfortunately, the amount of Fe material needed to correct Fe problems is often unknown and unsatisfactory results can occur from the use of insufficient or excessive amounts of Fe. Therefore, it is often wise to determine the appropriate amount and frequency of Fe to apply through trials. As a general guideline, foliar applications of Fe produce a rapid (2-3 days) but potentially short-termed green up. Granular application as high as 1/2 to 1 lb of actual iron / 1000 sq ft (from ferrous sulphate or ferrous ammonium sulphate) are sometimes used on turf, but, since these materials may cause severe and long lasting burns, frequent and light applications are probably more desirable. This is especially true since green up from granular fertilizers may also be temporary and repeat applications may be necessary.

IRON FERTILIZATION ON NON-CALCAREOUS SOILS

So far, this review has concentrated on correcting Fe chlorosis in turfgrass grown on calcareous soils with pH higher than 7. Although at low pH Fe deficiency is seldom a problem, turfgrass color can often be enhanced (made darker) by applications of Fe. A recent study at the University of Illinois, Urbana-Champaign (17) evaluated the use of foliar applications of Fe alone or in combination with N under color response of .Kentucky bluegrass grown on noncalcareous soils (pH = 5.9). Ferrous sulphate or iron chelate (Sequesterene 330) was applied at the rate of 1.1, 2.2, or 4.5 kg Fe/hectare in combination with either 0, 25 or 49 kg N/hectare. The color enhancement due to iron applications without N lasted from several weeks to several months depending on the weather following application. Use of Fe during cool, wet periods enhanced turf color for only two to three weeks and was therefore judged of limited value. Iron applications during cool, dry periods, however, enhanced turf color for several months. A treatment of 2.2 kg Fe/hectare from Fe chelate was rated the most effective. Combining Fe with 25 kg N/hectare, N/acre resulted in color enhancement equal to that caused by applying 49 kg N/hectare alone. The results of this study indicate that combining Fe with nitrogen can produce acceptable Kentucky bluegrass color on acid soils at lower rates of N fertilization.

As for turfgrass grown on modified soil, experiments conducted in Virginia (14, 16) on effects of Fe and nitrogen applied to creeping bentgrass putting green turf revealed that applications of Fe made in combination with nitrogen enhanced appearance, chlorophyll content, and early spring shoot growth. Spring and summer applications of N were beneficial to turfgrass color and further enhanced turf vigor when coupled with Fe fertilization. These researchers comment that although enhancement by Fe fertilization of creeping bentgrass quality was not always statistically significant, general increases in turf color, density, and root development were observed when Fe was applied. Other recent work by Virginia scientists (15) evaluated the influence of nitrogen fertilization on color, growth and physiology of creeping bentgrass grown on acidic soil (pH = 6.9) and treated with chelated Fe (FeDTPA) Applications of chelated Fe generally enhanced bentgrass color at all N levels used in this study. However, these researchers cautioned that although Fe can enhance turf color when applied in association with nitrogen, it should not be considered a replacement for nitrogen.

CONCLUSION

Iron chlorosis can be caused by several agronomic factors, not all of which are fully understood. Much work has been done and more is needed to uncover solutions to Fe chlorosis problems. Fortunately, existing knowledge plus the relatively large number of Fe containing materials in the market provide turfgrass managers with a variety of reasonable alternatives if they are willing to expend the time necessary to determine the cause of Fe chlorosis in their particular situation.

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Table 3. Color Rating of Kentucky Bluegrass Treated with Various Iron Materials on September 5, 1981.

Msteria1	Method of Application[y]	Rate kg Fe/ha (lb Fe/acre)	9/13/81	9/22/81	9/24/82
	Treatment		Color Rating[z]		
Sequesterene 330 (DTPA)	S	4.8 (4.3)	9.0 a	8.5 ab	4.3 cd
Seques terene 138 (EDDHA)	S	4.8 (4.3)	9.0 a	9.0 a	4.7 bc
Rayplex (Fe PF)	S	4.8 (4.30	8.0 ab	7.8 bc	5.7 b
Ferriplex 138 (EDDHA)	S	4.8 (4.3)	a.5 sb	8.2 ab	4.7 bc
Acid Iron (Mine Tailfng)	D	24.0 (21.5)	7.8 sb	9.0 a	9.0 a
Ferrous ammonium sulfate (FAS)	D	24.0 (21.5)	6.0 c	7.8 cd	8.0 a
Ferrous sulfate (FS)	D	24.0 (21.5)	6.2 c	6.8 d	7.7 a
Ammonium sulfate (AS)	D	16.0 kg N/ha (14.3 lb N/acre)	2.0 d	3.0 e	3.0 d
Control	-		2.0 d	3.5 e	3.7 cd

z Color rating: l=light yellow fading to white; 'I-lowest acceptable green; 9=dark green.
y S=sprayed; D-dry.
x Mean separation by Duncan's multiple range test, 5% level.

Adapted from: Minner sod Butler, 1984.

UC TURF CORNER

UC Turf Corner contains summaries of recently reported research results, abstracts of certain conference presentations, and announcements of new turf management publications. The source of each summary is given for the purpose of further reference.

Water-Related Studies in Tutfgrass

Abstracted by Forrest D. Cress[1]

Cool Season Turfgrasses

Kansas State University researchers have been studying the effects of soil compaction and different irrigation regimes on cool season turfgrasses. Here's a summary of findings from four of their recent research projects:

The influence of soil compaction on morphological and physiological aspects of 'Pennfine' perennial ryegrass, 'Baron' Kentucky bluegrass, and 'Kentucky 31' tall fescue was investigated.

The grasses were subjected to three compaction treatments: 1) no compaction except for routine mowing; 2) compaction with a smooth, power roller 12 times a week for 8 weeks; 3) compaction with the same roller 24 times a week for 8 weeks. The grasses were grown on a fine, montmorillonitic mesic Aquic Arquidoll soil.

Visual quality, percent turf cover, and total nonstructural carbohydrate declined for all three species as compaction stress increased. Eight months after the last compaction treatment, tall fescue and Kentucky bluegrass still showed reduced visual quality and percent cover.

Increased compaction reduced the verdure, shoot density and root growth of Kentucky bluegrass, decreased the verdure for tall fescue, but caused no adverse effects to the perennial ryegrass except for some reduction in root weight in the 12 times a week treatment.

Seeded in October, the grasses were rated the following August. Correlations of aeration porosity at -.lO bar and bulk density to plant responses were used to determine relative compaction tolerance. Visual quality rating and percent turf cover in August showed perennial ryegrass and Kentucky bluegrass to have an equal compaction tolerance which was greater than that of tall fescue.

(See "Influence of Soil Compaction of Three Turfgrass Species," by R. N. Carrow, Agronomy Journal, Vol. 72, November-December, 1980.)

In the second study, the effects of compaction on 'Baron' Kentucky bluegrass water use and growth under different irrigation treatments were measured.

A two-year-old stand of the bluegrass, grown on the same soil as that in the first study, was subjected to two levels of compaction (none and 30 passes per week with a roller) and two levels of irrigation (set schedule of 3.8 cm water per week plus rainfall and 3.8 cm when tensiometer at 10 cm depth read -.70 bar).

Soil compaction had no effect on root weight or distribution. Visual quality, shoot density, verdure and percent total cover were reduced by compaction. Total nonstructural carbohydrates

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weren't affected. In the surface 3cm of soil, compaction increased bulk density and moisture retention but reduced aeration porosity at -0.1 bar from 18.1 to 12.5 percent. Irrigation treatment didn't effect any physical properties of the soil.

Water use under the tensiometer irrigation treatment was 28 and 48 percent less on the noncompacted and compacted areas, respectively – without affecting turf quality- than on the set schedule irrigation plots. Water use over a nine-day period in August indicated that the turf grown under the tensiometer scheduled regime was physiologically or anatomically adapted to use less water even when it was available, and this adaptation wasn't due to differences in vegetative or root growth.

Compaction reduced water by 20 percent during the four-month study. During a nine-day period in August, compaction reduced water use by 3.5 and 11 percent for the tensiometer and set-scheduled treatments, respectively. This response, the Kansas State University researchers report, appeared to be due primarily to altered moisture retention properties and reduced shoot growth. Thus, they add, compacted and noncompacted sites should be irrigated on separate schedules.

[See "Kentucky Bluegrass Growth and Water Use Under different Soil Compaction and Irrigation Regimes:' by K. J. O'Neill and R. N. Carrow, Agronomy Journal, Vol. 74, November-December, 1982.)

In the third project, the Kansas State University researchers conducted field experiments to assess the potential of using plant canopy temperature – measured with an infrared thermometer-to schedule irrigation for Kentucky bluegrass.

The experiments also served to develop preliminary information for using stress degree day (SDD), crop water stress index (CWSI) , and critical point model (CPM) indices to schedule irrigations.

Data were collected in the summner and fall from differentially irrigated plots. Treatments were: 1) well watered-irrigation at soil water potential of -0.40MPa; 2) slightly stressed-irrigation at soil water potential of -0.07MPa; and 3) moderately stressed-irrigation at soil water potential of -0.40MPa.

Variables measured daily included canopy temperature, ambient air temperature, solar radiation, vapor pressure deficit, open pan evaporation, wind speed, soil water potential, volumetric water content, number of days after irrigation, and the number of days after mowing.

The data were used to develop the irigation scheduling indices that were evaluated the following year. Each of the indices was compared to tensiometer-based irrigation scheduling at -0.07MPa soil water potential. During a 25-day period of hot, dry weather, water use and number of irrigation events (in parentheses) were 98 (7), 112 (8), 140 (10) and 210 mm (15 times), respectively, for irrigation scheduling by tensiometer, SDDpos, CWSI, and CPM.

Shoot density, verdure, and root weight were not significantly different for the treatments, but visual quality was higher for the CPM and CWSl treatments-reflecting the greater amount of water applied, the Kansas researchers note. Further refinement of these indices could allow them to be useful tools for irrigation scheduling, they add.

(See "Canopy Temperature Based Irrigation Scheduling Indices for Kentucky Bluegrass Turf:' by C. S. Throssell, R. N. Carrow, and G. A. Milliken, Crop Science, Vol. 27, January-February, 1987.")

In the fourth project, 'Ram I' Kentucky bluegrass root responses to soil compaction and moisture stress conditioning and their effects on water use by the grass were studied in a greenhouse. Their effects on stomata1 diffusive resistance, leaf water potential and canopy minus air temperatures were also measured.

Compaction treatments included no compaction, compaction for 99 days, and compaction for 9 days. Irrigation regimes, started at the same time as the 99-days. Irrigation regimes, started at the same time as the 99-day compaction treatment, included well watered-irrigation at -0.045MPa - and water stressed-irrigation at 0.400MPa. Ninety-nine days after starting the preconditioning treatments and after watering each treatment to saturation, a dry-down cycle was started.

Compaction treatments reduced a specific oxygen diffusion rate for 143 hours compared with 26 hours in the uncompacted turf. Long-term compaction increased root weights in the upper 5 cm and decreased root weights in the lower 10 to 20 cm soil profile.

Short-term compaction decreased root weights only at 15 to 20 cm. Root porosity was increased by long-term compaction, but the greatest increase was for the combination of long-term compaction and water stress, resulting in root porosities of 23 percent. Plants with higher root porosities also showed greater water uptake during low soil oxygen conditions. Soil compaction reduced total water use and moisture extractions in the deeper zones.

Moisture stress preconditioning had no effect on root distribution but resulted in greater total water use, primarily from the 0- to 5- and 5- to 10-cm soil zones.

When the dry-down cycle began, stomata1 diffusive resistance, leaf water potential and canopy minus air temperatures were measured daily. Under low soil oxygen, stomatal diffusive resistance remained low for 2 days and then increased over a 5-day period for all treatments, even though leaf water potential didn't change until the fifth day after irrigation. By the 9th day after irrigation, stomatal diffusive resistance declined but then increased between the 10th and 13th day as soil water potential and leaf water potential decreased. As soil water deficits increased, plants preconditioned to long-term compaction or water-stress exhibited lower leaf water potential, higher stomatal diffusive resistance and higher canopy minus air temperatures compared with uncompacted or well-watered plants. Regardless of the cause for higher stomatal diffusive resistance (i.e., low soil oxygen, long-term compaction or water-stress preconditioning), the Kansas State University researchers point out, the result would be lower photosynthesis and greater high-temperature stress.

(See "Soil Compaction and Moisture Stress Preconditioning in Kentucky Bluegrass. I. Soil Aeration, Water Use, and Root Responses; II. Stomatal Resistance, Leaf Water Potential, and Canopy Temperatures," by M. L. Agnew and R. N. Carrow, Agronomy Journal, Vol. 77, November-December, 1985.)

WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in their original labeled containers In a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons. pets, and livestock.

Recommendations are based on the best information currently available, and treatments based on them should not leave residues exceeding the tolerance established for any particular chemical. Confine chemicals to the area being treated. THE GROWER IS LEGALLY RESPONSIBLE for residues on his crops as well as for problems caused by drift from his property to other propertles or crops.

Consult your County Agricultural Commissioner for correct methods of disposing of leftover spray material and empty containers. Never burn pesticide containers

PHYTOTOXICITY: Certain chemicals may cause plant injury if used at the wrong stage of plant development or when temperatures are too high. Injury may also result from excessive amounts or the wrong formulation or from mixing incompatible materials. Inert ingredients, such as wetters, spreaders, emulsifiers, diluents. and solvents, can cause plant in. jury. Since formulations are often changed by manufacturers. it is possible that plant injury may occur, even though no injury was noted in previous seasons.

NOTE: Progress reports give experimental data that should not be considered as recommendations for use. Until the products and the uses given appear on a registered pesticide label or other legal, supplementary direction for use, it is illegal to use the chemicals as described.

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