GCSAA CHAPTER COOPERATIVE RESEARCH PROGRAM

March 1998 to November 2001

Final Report

21 December 2001

Management of Annual Bluegrass Putting Greens in California

Investigators:
Robert Green, University of California, Riverside
Grant Klein, University of California, Riverside
Bill Richie, University of California, Riverside
Victor Gibeault, University of California, Riverside

Cooperators:
Bert Spivey, Industry Hills Golf Courses
Steve Cockerham, University of California, Riverside
Van Cline, The Toro Company
Janet Hartin, UCCE San Bernardino and Los Angeles Counties

UCR
TURF

TABLE OF CONTENTS

List of Tables

List of Tables *(continued)*

List of Tables *(continued)*

List of Figures

Acknowledgment

Thanks are given to the CGCSA and GCSAA for funding this project. Thanks are given to Industry Hills Golf Courses for the use of a practice putting green and invaluable assistance with the research project. Thanks also are given to The Toro Company for providing laboratory analyses of clipping tissues. Also, thanks are given to Western Farm Service for providing all liquid fertilizers.

Executive Summary

Most golf course superintendents in California are managing annual bluegrass as their putting green turfgrass. The major reason for this norm is the relatively mild climate of the region which usually results in newly established creeping bentgrass putting greens converting to annual bluegrass putting greens in 5 to 7 years. An exception to this rule is the more inland, hotter locations, such as Palm Springs, where bermudagrass and, less frequently, creeping bentgrass putting greens are maintained.

The major problems of managing annual bluegrass putting greens include: summer decline, which includes several issues, such as high temperature stress, disease activity, and salinity stress; seedhead production, especially in the spring; and puffiness during the growing season (October to December and February to June). We investigated fertility and water injection cultivation (WIC) treatments to improve plant performance and soil conditions during the warm season. However, it is possible that these treatments also may influence important plant characteristics during the cool season.

The objectives of this study were: 1) to determine the influence of the annual nitrogen and potassium fertility programs and foliar iron applications on plant performance [visual estimates of turfgrass quality and color, plant stress (e.g. mottling/patchiness and leaf wilting and rolling), disease activity, scalping, and seedhead coverage; root mass density, crown mass, and shoot density counts from plant cores; clipping yield; and concentrations of key nutrients in clipping tissue and soil]; 2) to determine the influence of WIC treatments during the warm season on plant performance; 3) to determine the influence of the fertility and WIC treatments on plant performance during the cool season; and 4) to determine fertility treatment effects on key nutrients in clipping tissue once every 6 weeks, utilizing both standard laboratory and near infrared reflectance spectroscopy (NIRS) methodologies. It should be noted that target ranges for elements in the clipping tissue of annual bluegrass basically have not been reported.

The location of this study was at Industry Hills Golf Courses, City of Industry, California, on an annual bluegrass practice putting green constructed to USGA specifications in 1978. The climate of this location, like much of southern California, is Mediterranean. Visual estimates indicated that the putting green was approximately 80% annual bluegrass and 20% creeping bentgrass. Results from a soil test taken on 3 June 1998, prior to the application of fertility treatments, showed: pH=6.7; EC_e=1.07 $dS \cdot m^{-1}$ (685 ppm total dissolved salts); SAR=2; ESP=2%; Fe=78.9 ppm; CEC=12.0 meq/100 g; OM=3.21%; Olsen-P=45.5 ppm; exchangeable K, Ca, Mg, Na=39, 1443, 170 and 115 ppm, respectively; and 88%, 10%, and 2% sand, silt, clay, respectively. The putting green was irrigated with effluent water with 1999 to 2000 average values as follows: pH=7.2; EC=1.01 $dS \cdot m^{-1}$ (646 ppm total dissolved salts); and SAR=3.2. The effluent irrigation annually supplied N at the approximate rate of 1.0 lb/1000 ft^2.

Eight liquid-applied fertility treatments and two summer-applied WIC treatments were arranged in a strip-plot design with four blocks (replications). Two nitrogen, two potassium, and two iron levels were factorially arranged into eight fertility treatments and were randomly assigned to 5.5- x 12.0-ft main plots that were within each 44.0- x 12.0-ft block. The fertility treatments are shown in a table below. The two WIC treatments were: a Toro HydroJect operated in the raised position once every 3 to 4 weeks from April through October and no WIC treatment. There were a total of 64, 5.5- x 6.0-ft subplots in this study.

Eight liquid-applied fertility treatments were tested in the annual bluegrass putting green management study. Fertility treatments were applied once every 3 weeks.

Treatment designation			lb/1000 ft^2 per year		
N	K_2O	Fe[z]	N	P_2O_5	K_2O
High	High	+	10.0	3.0	12.0
High	High	–	10.0	3.0	12.0
High	Low	+	10.0	3.0	4.0
High	Low	–	10.0	3.0	4.0
Low	High	+	5.0	3.0	12.0
Low	High	–	5.0	3.0	12.0
Low	Low	+	5.0	3.0	4.0
Low	Low	–	5.0	3.0	4.0

[z] Fe only applied to treatments indicated with "+" at 2.0 oz/1000 ft^2 $FeSO_4$ applied foliarly every 3 weeks.

Measurements that were collected during the study included: visual turfgrass quality and color ratings; Minolta spectrophotometer readings; elemental analyses of clippings; clipping yield; irrigation water analyses; soil elemental analyses; shoot density, crown mass, and root mass density from plant cores; and on-site air and soil temperatures. Visual estimates of turfgrass plant stress (e.g. coverage of mottling/patchiness and leaf wilting and rolling), disease activity coverage, seedhead coverage, and scalping coverage were taken on an as-needed basis. The purpose of these measurements was to help adequately describe plant and soil status and plant and soil responses to treatments and other effects, such as temperatures and turfgrass management practices. The practice putting green was managed in a similar manner as the greens on the golf course.

In terms of the results of this study, it should be noted that the Mediterranean climate of this region is very conducive to the growth of annual bluegrass, resulting in it being more competitive than creeping bentgrass on putting greens. A second point that should be made is that the practice putting green was irrigated with effluent. This resulted in the constant spoon-feeding of numerous plant nutrients, including N, P, K, Ca, Mg, and others. The approximate annual 889 mm (35 inches) of irrigation supplied N at the annual rate of 1.0 lb/1000 ft^2. Thus, the high and low N treatment rates were actually 11.0 and 6.0 lb/1000 ft^2 per year, respectively.

Nitrogen

The high N treatment rate was excessive, resulting in plant stress compared to the low N treatment rate. The high N treatment rate had: a similar overall average visual turfgrass quality rating (6.1 on a 1 to 9 scale) with lower ratings during late spring and summer; a higher overall average visual turfgrass color rating (6.8 on a 1 to 9 scale); an overall average of 106% more seedhead coverage; an overall average of 313% more

mottling/patchiness coverage (an indicator of plant stress, characterized by areas of turfgrass with a lighter green visual leaf color, lower visual shoot density, and greater vertical leaf extension rate); an overall average of 273% more leaf wilting and rolling coverage; an overall average of 55% more clipping yield; an overall average of 37% less root mass density of the 0.5- to 3.5-inch root zone; and an overall average of 17% less crown and plant mass.

The low N treatment rate may be close to the optimal N fertilizer rate for annual bluegrass. This is based on visual turfgrass quality (an overall average rating of 6.2) and color (an overall average rating of 6.3) and total N content of clippings. Both N treatments were basically within or higher than the target range of 4.5% to 6.0% total N in clippings of creeping bentgrass. The N rate of 6.0 lb/1000 ft^2 per year may need to be adjusted for other golf courses, depending on numerous conditions, such as: soil type, quality of irrigation water, infiltration rates, salinity and leaching requirements, climate, amount of rainfall, rounds of golf, N application schedule and N source, and Fe applications. Lastly, there is a need to define the minimal annual N fertilizer rate for annual bluegrass.

Iron

The foliar application of Fe as $FeSO_4$ at the rate of 2.0 oz/1000 ft^2 per 3 weeks increased visual turfgrass color ratings (plots treated with Fe had an overall average visual turfgrass color rating of 6.7 while plots not treated had a rating of 6.4) and total Fe content of clippings (however, both Fe treatments were basically within the target range of 100 to 300 ppm total Fe in clippings of creeping bentgrass). An Fe application once every 2 weeks would provide additional color improvement because our observations indicated that the turfgrass color response to $FeSO_4$ lasts for about 2 weeks. It is not unreasonable to believe that, in terms of visual turfgrass color, the amount of N fertilization may be reduced when a successful Fe fertilization program is used. This assumes that necessary growth is maintained.

Potassium

Other than total K content in clippings, we observed no difference between the high and low K treatments for all plant measurements. The high K_2O rate was 12.0 lb/1000 ft^2 per year while the low K_2O rate was 4.0 lb/1000 ft^2 per year. Our plant data were in spite of the fact that the low K treatment resulted in relatively low exchangeable K levels in the soil (overall average exchangeable K levels in the soil during 1999 and 2000 were 106.4 and 66.2 ppm for high and low K treatments, respectively). It should be noted that the effluent irrigation annually applied K at the approximate rate of 2.8 lb/1000 ft^2. Both K treatments were basically within or higher than the target range of 2.2% to 2.6% total K in clippings of creeping bentgrass. These data most likely support the approximate ratio of 3N:2 to 3 K_2O for a fertilizer schedule of a sand-based annual bluegrass putting green. Additional amounts of K above this ratio probably do not enhance the stress resistance of annual bluegrass.

Water injection cultivation during the summer

The summer WIC treatment significantly reduced leaf wilting and rolling during two of four rating dates. However, WIC treatments basically did not affect root mass density. Stated in the positive, WIC summer treatments neither harmed nor enhanced root mass density. This is notable because in a previous study on the same practice putting green, WIC treatments during the summer significantly increased field infiltration rates and lowered soil EC_e compared to check plots; also, root mass density was neither harmed nor enhanced by WIC treatments.

Introduction

Most golf course superintendents in California are managing annual bluegrass as their putting green turfgrass. The major reason for this norm is the relatively mild climate of the region which usually results in newly established creeping bentgrass putting greens converting to annual bluegrass putting greens in 5 to 7 years. An exception to this rule is the more inland, hotter locations, such as Palm Springs, where bermudagrass and, less frequently, creeping bentgrass putting greens are maintained.

The major problems of managing annual bluegrass putting greens include: summer decline, which includes several issues, such as high temperature stress, disease activity, and salinity stress; seedhead production, especially in the spring; and puffiness during the growing season (October to December and February to June). We investigated fertility and water injection cultivation (WIC) treatments to improve plant performance and soil conditions during the warm season. However, it is possible that these treatments also may influence important plant characteristics during the cool season.

Objectives

1. To determine the influence of the annual nitrogen and potassium fertility programs and foliar iron applications on plant performance [visual estimates of turfgrass quality and color, plant stress (e.g. mottling/patchiness and leaf wilting and rolling), disease activity, scalping, and seedhead coverage; root mass density, crown mass, and shoot density counts from plant cores; clipping yield; and concentrations of key nutrients in clipping tissue and soil]. Plant performance during the warm season was of special interest.

2. To determine the influence of WIC treatments during the warm season on plant performance (visual estimates of turfgrass quality and color, plant stress, disease activity, scalping, and seedhead coverage; root mass density, crown mass, and shoot density counts from plant cores).

3. To determine the influence of the fertility and WIC treatments on important plant characteristics (visual estimates of turfgrass quality, color, seedhead coverage, and disease activity; clipping yield; and concentrations of key nutrients in clipping tissue) during the cool season.

4. To determine fertility treatment effects on key nutrients in clipping tissue once every 6 weeks, utilizing both standard laboratory and near infrared reflectance spectroscopy (NIRS) methodologies. It should be noted that target ranges for elements in the clipping tissue of annual bluegrass basically have not been reported.

Location of Project

The location of this study was at Industry Hills Golf Courses, City of Industry, California, on an annual bluegrass practice putting green constructed to USGA specifications in 1978. The climate of this location, like much of southern California, is Mediterranean. Visual estimates indicated that the putting green was approximately 80% annual bluegrass and 20% creeping bentgrass. Results from a soil test taken on 3 June 1998, prior to the application of fertility treatments, showed: pH=6.7; EC_e=1.07 $dS \cdot m^{-1}$ (685 ppm total dissolved salts); SAR=2; ESP=2%; Fe=78.9 ppm; CEC=12.0 meq/100 g; OM=3.21%; Olsen-P=45.5 ppm; exchangeable K, Ca, Mg, Na=39, 1443, 170 and 115 ppm, respectively; and 88%, 10%, and 2% sand, silt, clay, respectively. The putting green was irrigated with effluent water with 1999 to 2000 average values as follows: pH=7.2; EC=1.01 $dS \cdot m^{-1}$ (646 ppm total dissolved salts); and SAR=3.2 (Table A-1). The effluent irrigation annually supplied N at the approximate rate of 48.8 $kg \cdot ha^{-1}$ (1.0 lb/1000 ft^2) (Fig. A-1, Tables A-2 to A-5).

Methods for Treatments

Eight liquid-applied fertility treatments and two WIC treatments were arranged in a strip-plot design with four blocks (replications). Two nitrogen, two potassium, and two iron levels were factorially arranged into eight fertility treatments and were randomly assigned to 1.7- x 3.7-m (5.5- x 12.0-ft) main plots that were within each 13.4- x 3.7-m (44.0- x 12.0-ft) block. Two WIC treatments were stripped across the fertility main plots and formed subplots. There were a total of 64, 1.7- x 1.8-m (5.5- x 6.0-ft) subplots in this study. More details concerning these treatments can be seen in Tables 1 to 3 and Figure 1. Tables A-6 and A-7 show when treatments were applied during the study.

Table 1. Eight liquid-applied fertility treatments tested in the annual bluegrass putting green management study.

Treatment designation			$kg \cdot ha^{-1}$ per year (lb/1000 ft^2 per year)		
N	K_2O	Fe[z]	N	P_2O_5	K_2O
High	High	+	487.9 (10.0)	146.4 (3.0)	585.5 (12.0)
High	High	–	487.9 (10.0)	146.4 (3.0)	585.5 (12.0)
High	Low	+	487.9 (10.0)	146.4 (3.0)	195.2 (4.0)
High	Low	–	487.9 (10.0)	146.4 (3.0)	195.2 (4.0)
Low	High	+	244.0 (5.0)	146.4 (3.0)	585.5 (12.0)
Low	High	–	244.0 (5.0)	146.4 (3.0)	585.5 (12.0)
Low	Low	+	244.0 (5.0)	146.4 (3.0)	195.2 (4.0)
Low	Low	–	244.0 (5.0)	146.4 (3.0)	195.2 (4.0)

[z] Fe only applied to treatments indicated with "+" at 6.1 $kg \cdot ha^{-1}$ (2.0 oz/1000 ft^2) $FeSO_4$ applied foliarly every 3 weeks. Fe treatments were individually applied to each plot, utilizing a CO_2 sprayer mounted on a cart, and not watered in. Finish spray volume was 855.3 $L \cdot ha^{-1}$ (2.1 gal/1000 ft^2).

Methods for Treatments

Table 2. N, P_2O_5, and K_2O application schedule for the annual bluegrass putting green management study.

	Application date																		
Fertilizer component	6 Jan.	27 Jan.	17 Feb.	10 Mar.	31 Mar.	21 Apr.	12 May	2 June	23 June	14 July	4 Aug.	25 Aug.	15 Sept.	6 Oct.	27 Oct.	17 Nov.	8 Dec.	22 Dec.	Annual total
	kg·ha^{-1} (lb/1000 ft^2)																		
N (high rate)	24.4 (.50)	29.3 (.60)	36.6 (.75)	36.6 (.75)	36.6 (.75)	36.6 (.75)	26.8 (.55)	19.5 (.40)	14.6 (.30)	14.6 (.30)	14.6 (.30)	14.6 (.30)	14.6 (.30)	41.5 (.85)	36.6 (.75)	36.6 (.75)	29.3 (.60)	24.4 (.50)	487.9 (10.0)
N (low rate)	6.1 (.125)	9.8 (.20)	9.8 (.20)	23.2 (.475)	14.6 (.30)	14.6 (.30)	14.6 (.30)	9.8 (.20)	9.8 (.20)	9.8 (.20)	9.8 (.20)	9.8 (.20)	9.8 (.20)	34.2 (.70)	19.5 (.40)	19.5 (.40)	19.5 (.40)	–	244.0 (5.0)
P_2O_5	–	–	–	24.4 (.50)	24.4 (.50)	24.4 (.50)	–	–	–	–	–	–	–	24.4 (.50)	24.4 (.50)	24.4 (.50)	–	–	146.4 (3.0)
K_2O (high rate)	48.8 (1.0)	48.8 (1.0)	48.8 (1.0)	48.8 (1.0)	48.8 (1.0)	48.8 (1.0)	48.8 (1.0)	36.6 (.75)	14.6 (.30)	14.6 (.30)	14.6 (.30)	14.6 (.30)	14.6 (.30)	39.0 (.80)	36.6 (.75)	34.2 (.70)	24.4 (.50)	–	585.5 (12.0)
K_2O (low rate)	–	–	–	–	36.6 (.75)	36.6 (.75)	36.6 (.75)	31.7 (.65)	14.6 (.30)	9.8 (.20)	9.8 (.20)	9.8 (.20)	9.8 (.20)	–	–	–	–	–	195.2 (4.0)

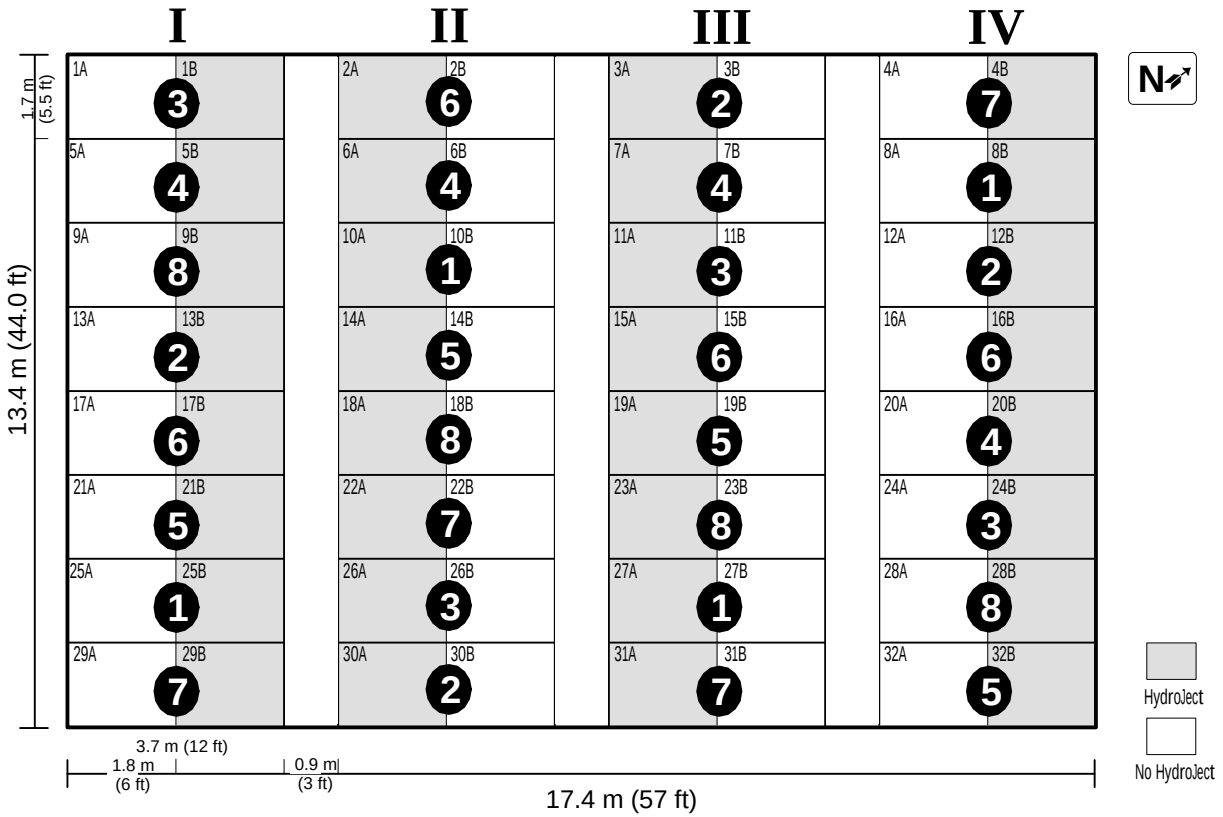
Note: N sources were ammonium nitrate [20-0-0; 1.27 kg·L^{-1} (10.55 lb/gal)] for December, January, and February; ammonium sulfate [8-0-0-9S; 1.23 kg·L^{-1} (10.22 lb/gal)] for March and April; and low biuret urea [20-0-0; 1.12 kg·L^{-1} (9.35 lb/gal)] from May through November. P source was ammonium polyphosphate [10-34-0; 1.38 kg·L^{-1} (11.5 lb/gal)]. K source was potassium sulfate ESP-K [1-0-8-2.5S; 1.17 kg·L^{-1} (9.7 lb/gal)]. Finish spray volume for each treatment application was 855.3 L·ha^{-1} (2.1 gal/1000 ft^2). All treatments were applied with a CO_2 sprayer mounted on a cart. N, P_2O_5, and K_2O treatments were watered in.

Table 3. Water injection cultivation treatments for the annual bluegrass putting green management study.

Treatment level	Treatment specifications	
Cultivation	*Equipment:*	Toro HydroJect 3000; #53 nozzles, 11 operating.
	Settings:	Run in the raised (transport) position; set to second greatest hole density.
	Result:	Hole spacing approximately 7.6 x 7.6 cm (3.0 x 3.0 inch).
		Holes created by the WIC treatment were ≈3 (0.1 inch) diameter x 108 mm (4.3 inches) deep. They also had a surface entry [≈9 mm (0.4 inch)] that was wider than the hole.
	Frequency:	Once every 3 to 4 weeks from April through October[z].
No cultivation	No WIC treatment.	

[z]Cultivation treatments applied as follows: in 1998, once every 4 weeks from June through October; in 1999, once every 3 weeks from May through October; and in 2000, once every 3 weeks from April through September.

Figure 1. Plot plan for the annual bluegrass management study.



Treatment designation	kg·ha^{-1} per year (lb/1000 ft^2 per year) N	P_2O_5	K_2O	Treatment designation	kg·ha^{-1} per year (lb/1000 ft^2 per year) N	P_2O_5	K_2O
1. High N/High K/ + Fe	487.9 (10.0)	146.4 (3.0)	585.5 (12.0)	5. Low N/High K/ + Fe	244.0 (5.0)	146.4 (3.0)	585.5 (12.0)
2. High N/High K/– Fe	487.9 (10.0)	146.4 (3.0)	585.5 (12.0)	6. Low N/High K/– Fe	244.0 (5.0)	146.4 (3.0)	585.5 (12.0)
3. High N/Low K/ + Fe	487.9 (10.0)	146.4 (3.0)	195.2 (4.0)	7. Low N/Low K/ + Fe	244.0 (5.0)	146.4 (3.0)	195.2 (4.0)
4. High N/Low K/– Fe	487.9 (10.0)	146.4 (3.0)	195.2 (4.0)	8. Low N/Low K/– Fe	244.0 (5.0)	146.4 (3.0)	195.2 (4.0)

+ Fe = 6.1 kg·ha^{-1} (2 oz/1000 ft^2) $FeSO_4$ applied foliarly every 3 weeks.

Methods for Measurements

Measurements that were collected during the annual bluegrass putting green management study included: visual ratings; Minolta spectrophotometer readings; elemental analyses of clippings; clipping yield; irrigation water analyses; soil elemental analyses; shoot density, crown mass, and root mass density from plant cores; and on-site air and soil temperatures. The purpose of these measurements was to help adequately describe plant and soil status and plant and soil responses to treatments and other effects, such as temperatures and turfgrass management practices. An approximate schedule for routine measurement collection during the study is show in Table 4 while a brief description of the methods for the measurements is shown in Table 5. Tables A-6 and A-7 show when measurements were taken during the study.

Table 4. Approximate schedule for routine measurement collection during the annual bluegrass management study.

Date	Visual estimates of turfgrass quality and color	Minolta spectro-photometer readings	Clipping elemental analyses	Clipping yield	Irrigation water analyses	Soil elemental analyses	Plant morph-ological analyses
19 Jan.	*	*	*				
2 Mar.	*	*	*				
23 Mar.				*	*		
13 Apr.	*	*	*				
7 May						*	*
25 May	*	*	*				
6 July	*	*	*				
28 July				*	*		
17 Aug.	*	*	*				
10 Sept.						*	*
28 Sept.	*	*	*				
9 Nov.	*	*	*				
21 Dec.				*	*		

Note: Visual estimates of turfgrass plant stress (e.g. coverage of mottling/patchiness and leaf wilting and rolling), disease activity coverage, seedhead coverage, and scalping coverage were taken on an as-needed basis.

Methods for Measurements

Table 5. Brief description of the methods for the measurements taken during the annual bluegrass putting green management study.

1. Visual estimates of turfgrass putting green quality and color were taken every 6 weeks from subplots. Ratings were taken on a 1 to 9 scale, with 9=best quality putting green or darkest green color, 5=minimally acceptable quality or color, and 1=worst quality putting green or brown color. Starting 9 Feb. 2000, color ratings were normally taken every 3 weeks. Measurements were normally taken 13 to 14 d after fertilizer treatment applications.

2. Spectrophotometer readings were taken with a Minolta CM-525i using L*a*b* color space. Measurements were taken once every 6 weeks from main plots, three subsamples per main plot (one from each of the subplots and one between the two subplots). Starting 9 Feb. 2000, spectrophotometer readings were normally taken every 3 weeks. Measurements were normally taken 13 to 14 d after fertilizer treatment application.

3. Visual estimates of percent coverage of mottling/patchiness, leaf wilting and rolling, disease activity, seedheads, and scalping were taken from subplots on an as-needed basis. Mottling/patchiness coverage was an indicator of plant stress and characterized by areas of turfgrass with a lighter green visual leaf color, lower visual shoot density, and greater vertical leaf extension rate (data not shown).

4. Elemental analyses of clippings were collected from main plots once every 6 weeks. Analyses were conducted by laboratory methodology: total N, C, and S using the combustion gas analyzer method; total P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, B, Mo, Al, and Ti using the dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry method (Table A-8). Samples were normally collected 13 to 14 d after fertilizer treatment applications.

5. Clipping yield of 1 d growth was collected from each main plot on 21 Dec. 1998; 23 Mar., 30 July, and 21 Dec. 1999; and 22 Mar. and 26 July 2000. Samples represented 66% of the total surface area of the main plots and were reported as g dry clippings/2.0 m^2 (22 ft^2) per day. Samples were collected 13 to 16 d after fertilizer treatment application.

6. Irrigation water samples were collected on the same dates as clipping yield. Frozen samples were sent to Division of Agriculture and Natural Resources (DANR) Analytical Laboratory and analyzed for pH, EC, Ca, Mg, Na, SAR, ESP, Cl, B, HCO_3, CO_3, SO_4-S, NH_4-N, NO_3-N, P, K-soluble, Cu, Fe, Mn, Se, and Zn (Table A-9). Irrigation water samples also were collected from May 2000 to Aug. 2001 and analyzed for ammonia N, organic N, nitrate N, and nitrite N at the laboratory of the San Jose Creek Water Reclamation Plant, East (Fig. A-1, Tables A-2 to A-5).

7. Analyses were made of the 1.3- to 8.9-cm (0.5- to 3.5-inch) root-zone soil for TKN; Olsen-P; exchangeable K; exchangeable Ca; exchangeable Mg; exchangeable Na; EC_e; SAR; and soluble Ca, Mg, and Na (pH and CEC were included in analyses for 2000) (see Table A-9 for methodology details). Samples included 14 to 20, 2-cm diameter cores taken with Oakfield tubes collected from each main plot over three of the four replications. A grid was used to ensure that no portion of the plot was sampled more than once for the duration of the study. Sample dates were 7 May and 10 Sept. 1999; and 5 May and 8 Sept. 2000 (16 d after fertilizer treatment applications). Samples were sent to the DANR Analytical Laboratory for analyses.

8. Analyses of shoot density, crown mass, and root mass density [1.3- to 8.9 cm (0.5- to 3.5-inch root zone)] were made from five 2-cm diameter cores taken with Oakfield tubes. Samples were collected from each subplot over three of the four replications. A grid was used to ensure that no portion of the subplot was sampled more than once for the duration of the study. Samples were collected on the same dates as soil analyses (16 d after fertilizer treatment applications). Samples analyzed at the UC Riverside Turfgrass Project laboratory facility.

9. On-site air and soil temperatures were taken hourly with Onset Stowaway XTI data microloggers and downloaded every 3 weeks. The air temperature sensor was located at a 1.83 m (6.0 ft) height within the canopy of a tree adjacent to the research plot, and was protected from the direct light of the sun with a lamp-shade-shaped metal shield. The soil temperature sensor was installed 5.1 cm (2.0 inches) below the soil surface of the research plot. These data were collected from 7 June 1998 to 23 Sept. 2000.

Methods for Plot Maintenance

The practice putting green was managed in a similar manner as the greens on the golf course. Table 6 shows the turf management practices. Tables A-6 and A-7 also show when turf management practices occurred.

Table 6. Plot maintenance protocol for the annual bluegrass management study from June 1998 to Sept. 2000.

1. Depending on the season of the year, mowed at a 3.30- to 4.75-mm (0.130- to 0.187-inch) height of cut, four or more times per week with a Jacobsen 56-cm (22-inch) walking greensmower or a Toro triplex mower (used on weekends, except prior to tournaments).
2. Cultivation in October with 1.59-cm (0.625-inch) hollow tines (cores removed) followed by topdressing with sand with a Turfco Metr-Matic at setting 4 (total sand applied = 1.25 hoppers of sand; total of 10 passes with topdresser). Plots also cultivated, according to protocol, with Toro HydroJect once every 4 weeks from June through Oct. 1998, once every 3 weeks from May through Oct. 1999, and once every 3 weeks from Apr. through Sept. 2000.
3. Verticut [1.59-mm (0.063-inch) bench setting] and topdressed June, July, September, November, December, February, March and April. In 1998, verticut on 16 June, 29 June, 27 July, 8 Sept., 19 Nov., and 11 Dec. (with groomers); in 1999 on 2 Feb., 2 Mar., 29 Mar., 9 Apr., 4 May, 10 May, 1 June, 22 June, and 31 Aug.; and in 2000 on 4 Jan., 3 Feb., 7 Mar., 10 Apr., 26 Apr., 8 May, 6 June, and 5 Sept.
4. Grooming as needed.
5. Light topdressing as needed. Applied Oct., Nov., Dec. 1998; Feb., Mar., May, July, Aug., Oct. 1999; and Jan., Feb., Mar., May, June, July, and Sept. 2000.
6. Insecticides and herbicides applied as needed (from June 1998 to Sept. 2000); fungicides applied to prevent moderate to severe disease activity. Applications were made to control cutworms (Dursban or Scimitar); to prevent anthracnose (Banner or a combination of Heritage and Daconil); to control cool-season brown patch (combination of Prostar and Banner); to prevent dollar spot (Heritage or Heritage in combination with Curalain or Fore); to control dollar spot (Chipco, Daconil, or Eagle); to control pink snow mold [Terraclor (PCNB)]; to prevent summer patch (Banner, Heritage, or Heritage in combination with Curalain, Daconil or Fore); and crabgrass preemergence (Betasan 4E).
7. Plots irrigated for optimum growth and playability.
8. Plots syringed and hand-watered to prevent drought symptoms, as needed.
9. Plots leached with 39 to 78 mm (1.5 to 3.0 inches) of water the last Sunday of each summer month, or as needed. Leaching occurred in June, July, Sept. 1998; Feb., June, July, Aug., Sept. 1999; and May 2000 (a natural leaching occurred in Apr. 2000 due to rainfall and leaching events scheduled for June and July 2000 were canceled due to high temperatures).

Results

In the results and discussion sections it will be assumed that effluent irrigation annually supplied N at the rate of 48.8 $kg \cdot ha^{-1}$ (1.0 lb/1000 ft^2) (Fig. A-1, Tables A-2 to A-5). Thus, the high and low N fertility treatments rates were actually 536.7 and 292.8 $kg \cdot ha^{-1}$ (11.0 and 6.0 lb/1000 ft^2) per year, respectively.

Visual turfgrass quality

Considering all the treatments, basically only N significantly affected visual turfgrass quality ratings (Fig. 3, Tables 7 and 8). One notable exception was that the overall Fe effect was significant. The additional N from the high N treatment did not improve visual turfgrass quality and in fact decreased it, especially during late spring and summer. Ratings for the high N treatment ranged from 5.0 to 7.2 with lower ratings during late spring and summer. Ratings for the low N treatment ranged from 5.7 to 7.0. Under the conditions of this study and in terms of visual turfgrass quality, the high N rate [536.7 $kg \cdot ha^{-1}$ (11.0 lb/1000 ft^2) per year] was excessive and the low N rate [292.8 $kg \cdot ha^{-1}$ (6.0 lb/1000 ft^2) per year] was sufficient to optimal.

Visual turfgrass color

Nitrogen and iron were the only treatments to significantly affect visual turfgrass color ratings (Fig. 4, Tables 8 and 9). Treatment with the high N rate and application of Fe [$FeSO_4$ at 6.1 $kg \cdot ha^{-1}$ (2.0 oz/1000 ft^2) per 3 weeks] resulted in higher color ratings. Ratings for the high N treatment ranged from 5.8 to 7.9 while ratings for the low N treatment ranged from 5.6 to 7.5. The high N treatment effect was associated with the cool season when more N fertilizer was applied (Table 2). This was especially evident during the winter and early spring. Visual turfgrass color ratings for plots treated with Fe ranged from 5.9 to 7.9 while ratings for plots not treated with Fe ranged from 5.8 to 7.5. The Fe treatment effect was more evident during 1998 and 1999 than during 2000.

Seedhead coverage

Nitrogen was the only treatment to significantly effect percent coverage of seedheads (Fig. 5, Tables 8 and 10). Considering the overall percent seedhead coverage (Table 8), plots receiving the high N treatment had an average of 106% more seedhead coverage than plots receiving the low N treatment. This was calculated as follows: [(observation–control)/control] x 100, where the low N treatment was considered the control. Plots receiving the high N treatment ranged from 4% to 66% seedhead coverage while plots receiving the low N treatment ranged from 3% to 45%. Seedhead coverage appeared to be highest during the spring and fall.

Increased seedhead production can be associated with undesirable growing conditions and plant stress. Considering other significant effects associated with the high N treatment (reduced visual turfgrass quality, increased mottling/patchiness, increased leaf wilting and rolling, increased clipping yield, and reduced root and crown mass), the increased seedhead coverage was most likely due to plant stress induced by excessive N fertilization.

Mottling/patchiness coverage

Mottling/patchiness coverage was an indicator of plant stress and characterized by areas of turfgrass with lighter green visual leaf color, lower visual shoot density, and greater vertical leaf extension rate (data not shown). Basically, only N treatments significantly affected percent coverage of mottling/patchiness (Fig. 6, Table 11). Plots receiving the high N treatment had an overall average 313% more mottling/patchiness coverage than plots receiving the low N treatment. Plots receiving the high N treatment ranged from 15% to 80% coverage of mottling/patchiness while plots receiving the low N treatment ranged from 4% to 40%. Mottling/patchiness appeared to be most prominent during late spring and summer.

Coverage of disease activity, leaf wilting and rolling, and scalping

Basically, only N and WIC treatments significantly affected percent coverage of leaf wilting and rolling (Fig. 7, Table 12). Plots receiving the high N treatment had an overall average 273% more leaf wilting and rolling coverage than plots receiving the low N treatment. Plots receiving the high N treatment ranged from 27% to 56% coverage of leaf wilting and rolling while plots receiving the low N treatment ranged from 6% to 26%.

On two of the four rating dates the cultivation effect was significant. Plots which were cultivated by WIC had an overall average 21% less percent coverage of leaf wilting and rolling. Plots cultivated by WIC ranged from 14% to 33% coverage of leaf wilting and rolling while plots which were not cultivated by WIC ranged from 19% to 49%.

Only N treatments significantly affected percent coverage of cool-season brown patch (Table 12). Plots receiving the high N treatment had lower cool-season brown patch coverage than plots receiving the low N treatment. Plots receiving the high N treatment ranged from 0.8% to 1.4% coverage of cool-season brown patch while plots receiving the low N treatment had 2.9%. Cool-season brown patch only occurred during the spring and summer of 1999.

Only N treatments significantly affected percent coverage of scalping (Table 12). Plots receiving the high N treatment had an overall average 267% more scalping coverage than plots receiving the low N treatment. Plots receiving the high N treatment ranged from 3% to 15% coverage of scalping while plots receiving the low N treatment ranged from 0% to 6%. Scalping only occurred during the summer of 2000.

Clipping yield

Nitrogen was the only treatment to significantly affect clipping yield (Fig. 8, Table 13). Since data were collected from main plots, the cultivation effect could not be tested. Plots receiving the high N treatment had an overall average 55% more clipping yield than plots receiving the low N treatment. Clipping yield for plots receiving the high N treatment ranged from 1.53 to 19.61 g/2.0 m^2 per 1 d while clipping yield for plots receiving the low N treatment ranged from 0.83 to 17.34 g/2.0 m^2 per 1 d. It should be noted that sample date had a much greater effect on clipping yield than N treatments. Clipping yield was highest in July and lowest in December. Differences in air and soil temperatures (Fig. 2) coupled with a Mediterranean climate versus differences in N applications (Tables 2 and A-2) most likely were the cause for clipping yield differences between sample dates. Mowing height ranged from 3.30 to 3.96 mm (0.130 to 0.156 inch) during the collection of clipping yield (Table A-6) and was most likely not a major factor contributing to clipping yield differences among sample dates.

Shoot number; root mass density; root, crown, and total plant mass

It should be noted that these data were taken from cores that were collected in early May and September. Nitrogen,

K, Fe, and cultivation treatments basically did not affect shoot number (Fig. 9, Table 14).

Nitrogen was basically the only treatment to significantly affect root mass density and root mass (Fig. 9, Tables 14 and 15). Plots treated with the high N treatment had an overall average 37% less root mass density and root mass than plots treated with the low N treatment. Root mass density for plots receiving the high N treatment ranged from 0.039 to 0.130 $mg \cdot cm^{-3}$ while root mass density for plots receiving the low N treatment ranged from 0.048 to 0.329 $mg \cdot cm^{-3}$. It should be noted that there was a dramatic decrease in root mass density from May to September 1999 for both N treatments. The May 1999 sample date was the highest among all 1999 and 2000 sample dates for root mass density.

Nitrogen was basically the only treatment to significantly affect crown mass and total plant mass (Table 15). Plots treated with the high N treatment had an overall average 17% less crown and plant mass. Crown mass for plots receiving the high N treatment ranged from 0.5122 to 0.6843 g/14.2 cm^2 while plots receiving the low N treatment ranged from 0.6164 to 0.8323 g/14.2 cm^2. Total plant mass for plots receiving the high N treatment ranged from 0.5190 to 0.6885 g while plots receiving the low N treatment ranged from 0.6250 to 0.8422 g.

Total N content of clippings

Nitrogen was basically the only treatment to significantly affect total N content of clippings (Fig. 10, Table 16). Since clippings were collected from main plots, the cultivation effect could not be tested. Plots receiving the high N treatment had a higher total N content of clippings than plots receiving the low N treatment. Plots treated with the high N treatment ranged from 4.50% to 6.96% total N while plots treated with the low N treatment ranged from 4.24% to 5.81%. Total N content of clippings appeared to be highest during the winter and lowest during late spring and early summer. Both N treatments were basically within or higher than the target range of 4.5% to 6.0% total N in clippings of creeping bentgrass.

Total K content of clippings

Nitrogen and K were basically the only treatments to significantly affect total K content of clippings (Fig. 11, Table 17). Plots receiving the high N or high K treatments had a higher total K content of clippings than plots receiving the low N or K treatments, respectively. Plots treated with the high N treatment ranged from 2.20% to 3.91% total K while plots receiving the low N treatment ranged from 2.18% to 3.84%. Plots treated with the high K treatment [585.5 $kg \cdot ha^{-1}$ (12.0 lb/1000 ft^2) K_2O per year] ranged from 2.22% to 3.89% total K while plots receiving the low K treatment [195.2 $kg \cdot ha^{-1}$ (4.0 lb/1000 ft^2) K_2O per year] ranged from 2.16% to 3.86%. The high N treatment resulted in significantly higher total K content of clippings during November, January, and July during 1998 to 2000. The high K treatment resulted in significantly higher total K content of clippings basically during January to May. All N and K treatments were basically within or higher than the target range of 2.2% to 2.6% total K in clippings of creeping bentgrass.

Total P content of clippings

All treatments received the same amount of P [146.4 $kg \cdot ha^{-1}$ (3.0 lb/1000 ft^2) P_2O_5 per year] (Tables 1 and 2). However, N treatments significantly affected total P content of clippings (Fig. 12 and Table 18). There was not a clear trend of one N treatment having a higher total P content of clippings than the other. Plots treated with the high N treatment ranged from 0.39% to 0.66% total P while plots receiving the low N treatment ranged from 0.43% to 0.62%. Both N treatments were basically within the target range of 0.3% to 0.6% total P in clippings for creeping bentgrass.

Total Fe content of clippings

Nitrogen and Fe were the only treatments to significantly affect total Fe content of clippings (Fig. 13, Table 19). Plots which received the high N treatment or were treated with Fe [6.1 kg·ha^{-1} (2.0 oz/1000 ft^2) $FeSO_4$ per 3 weeks] had a higher total Fe content of clippings than plots which received the low N treatment or were not treated with Fe, respectively. Plots treated with the high N treatment ranged from 97 to 234 ppm total Fe while plots receiving the low N treatment ranged from 91 to 214 ppm. Plots treated with Fe ranged from 97 to 253 ppm total Fe while plots not treated with Fe ranged from 90 to 221 ppm. The high N treatment resulted in significantly higher total Fe content of clippings during the spring and summer while the application of Fe resulted in significantly higher total Fe content of clippings during all seasons of the year. All N and Fe treatments were basically within the target range of 100 to 300 ppm total Fe in clippings of creeping bentgrass.

Total C, S, Ca, Mg, Mn, B, Cu, Zn, Mo, Na, Al, and Ti content of clippings

Though these elements were not directly related to the objectives of this study, they were analyzed and are reported in Tables A-10 to A-21. Nitrogen, K, and Fe treatments significantly affected the clipping concentration of a number of these elements. It is possible that these data will be reported in a technical paper.

Determination of key nutrients in clipping tissue utilizing near infrared reflectance spectroscopy (NIRS) and Minolta spectrophotometer readings

Currently, the Toro Company has determined that NIRS is reliable for N clipping content but not for P and K. They are in the process of trying to improve the prediction equations for P and K. Thus, the NIRS objective of this study was not feasible.

Though the Minolta spectrophotometer readings were collected, they were not reported because these readings were part of the NIRS objective.

Soil and water test results

Soil in the 1.3- to 8.9-cm (0.5- to 3.5-inch) deep root zone was sampled during the early part of May and September during 1999 and 2000 (Tables 20 to 23). The May and September sample dates were chosen to bracket the summer and to determine the effects of the relatively heavy fertilizer schedule during the fall through spring versus the relatively light fertilizer schedule during the summer (Table 2).

In terms of consistent effects of treatments, the high K treatment resulted in significantly higher levels of exchangeable K on three of four sample dates. The high K treatment had significantly higher soil exchangeable K than the low K treatment in both May sample dates. This shows that exchangeable K was built up in the soil following the heavy fertilization schedule from the fall through spring.

The following is a list of selected overall average soil salinity and fertility levels. Table A-9 describes soil analyses methodologies:

EC_e	1.59 dS·m^{-1}	Low total salinity
SAR	3.4	No Na-induced permeability problems
ESP (%)	3	No Na-induced permeability problems
Olsen-P	58.5 ppm	High P sufficiency level

Exchangeable K		
High K treatment	106.4 ppm	Moderate K sufficiency level
Low K treatment	66.2 ppm	Low K sufficiency level
Exchangeable Ca	1572.1 ppm	High Ca sufficiency level
Exchangeable Mg	197.1 ppm	Sufficient Mg sufficiency level
Exchangeable Na	174.3 ppm	Very low Na level
pH	6.7	Desirable pH
CEC	22.1 meq/100 g	Desirable CEC

Table A-1 shows the results of the irrigation water analyses and Table A-2 shows that approximately 889 mm (35 inches) of irrigation water was applied annually on the putting green. The following is a list of several nutrients and Na that are annually applied through the irrigation water:

P	4.9 $kg \cdot ha^{-1}$ (0.1 lb/1000 ft^2)
K	136.6 $kg \cdot ha^{-1}$ (2.8 lb/1000 ft^2)
Ca	487.9 $kg \cdot ha^{-1}$ (10.0 lb/1000 ft^2)
Mg	165.9 $kg \cdot ha^{-1}$ (3.4 lb/1000 ft^2)
Na	1014.8 $kg \cdot ha^{-1}$ (20.8 lb/1000 ft^2)

Discussion

This study tested spray-applied N, K, and Fe, and WIC treatments on an annual bluegrass practice putting green which was constructed to USGA specifications in 1978. The practice putting green was located on a golf course in southern California. It should be noted that the Mediterranean climate of this region is very conducive to the growth of annual bluegrass, resulting in it being more competitive than creeping bentgrass on putting greens. A second point that should be made is that the practice putting green was irrigated with effluent. This resulted in the constant spoon-feeding of numerous plant nutrients, including N, P, K, Ca, Mg, and others. The approximate annual 889 mm (35 inches) of irrigation supplied N at the annual rate of 48.8 kg·ha^{-1} (1.0 lb/1000 ft^2). Thus, the high and low N treatment rates were actually 536.7 and 292.8 kg·ha^{-1} (11.0 and 6.0 lb/1000 ft^2) per year, respectively.

Nitrogen

The high N treatment rate was excessive, resulting in plant stress compared to the low N treatment rate. The high N treatment rate had: a similar overall average visual turfgrass quality rating (6.1 on a 1 to 9 scale) with lower ratings during late spring and summer; a higher overall average visual turfgrass color rating (6.8 on a 1 to 9 scale); an overall average of 106% more seedhead coverage; an overall average of 313% more mottling/patchiness coverage (an indicator of plant stress, characterized by areas of turfgrass with a lighter green visual leaf color, lower visual shoot density, and greater vertical leaf extension rate); an overall average of 273% more leaf wilting and rolling coverage; an overall average of 55% more clipping yield; an overall average of 37% less root mass density of the 1.3- to 8.9-cm (0.5- to 3.5-inch) root zone; and an overall average of 17% less crown and plant mass.

The low N treatment rate may be close to the optimal N fertilizer rate for annual bluegrass. This is based on visual turfgrass quality (an overall average rating of 6.2) and color (an overall average rating of 6.3) and total N content of clippings. Both N treatments were basically within or higher than the target range of 4.5% to 6.0% total N in clippings of creeping bentgrass. The N rate of 292.8 kg·ha^{-1} (6.0 lb/1000 ft^2) per year may need to be adjusted for other golf courses, depending on numerous conditions, such as: soil type, quality of irrigation water, infiltration rates, salinity and leaching requirements, climate, amount of rainfall, rounds of golf, N application schedule and N source, and Fe applications. Lastly, there is a need to define the minimal annual N fertilizer rate for annual bluegrass.

Iron

The foliar application of Fe as $FeSO_4$ at the rate of 6.1 kg·ha^{-1} (2.0 oz/1000 ft^2) per 3 weeks increased visual turfgrass color ratings (plots treated with Fe had an overall average visual turfgrass color rating of 6.7 while plots not treated had a rating of 6.4) and total Fe content of clippings (however, both Fe treatments were basically within the target range of 100 to 300 ppm total Fe in clippings of creeping bentgrass). An Fe application once every 2 weeks would provide additional color improvement because our observations indicated that the turfgrass color response to $FeSO_4$ lasts for about 2 weeks. It is not unreasonable to believe that, in terms of visual turfgrass color, the amount of N fertilization may be reduced when a successful Fe fertilization program is used. This assumes that necessary growth is maintained.

Potassium

Other than total K content in clippings, we observed no difference between the high and low K treatments for all plant measurements. The high K_2O rate was 585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) per year while the low K_2O rate was 195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) per year. Our plant data were in spite of the fact that the low K treatment resulted in relatively

low exchangeable K levels in the soil (overall average exchangeable K levels in the soil during 1999 and 2000 were 106.4 and 66.2 ppm for high and low K treatments, respectively). It should be noted that the effluent irrigation annually applied K at the approximate rate of 136.6 $kg \cdot ha^{-1}$ (2.8 lb/1000 ft^2). Both K treatments were basically within or higher than the target range of 2.2% to 2.6% total K in clippings of creeping bentgrass. These data most likely support the approximate ratio of 3N:2 to 3 K_2O for a fertilizer schedule of a sand-based annual bluegrass putting green. Additional amounts of K above this ratio probably do not enhance the stress resistance of annual bluegrass.

Water injection cultivation during the summer

The summer WIC treatment significantly reduced leaf wilting and rolling during two of four rating dates. However, WIC treatments basically did not affect root mass density. Stated in the positive, WIC summer treatments neither harmed nor enhanced root mass density. This is notable because in a previous study on the same practice putting green, WIC treatments during the summer significantly increased field infiltration rates and lowered soil EC_e compared to check plots; also, root mass density was neither harmed nor enhanced by WIC treatments.

Figure 2a. Weekly mean warm [1200 HR to 1600 HR (12 noon to 4 p.m.)] and cool [0200 HR to 0600 HR (2 a.m. to 6 a.m.)] **air temperatures** [at a 1.8-m (6-ft) height] on-site at Industry Hills Golf Courses, Industry, Calif., from 7 June 1998 to 23 Sept. 2000**.**

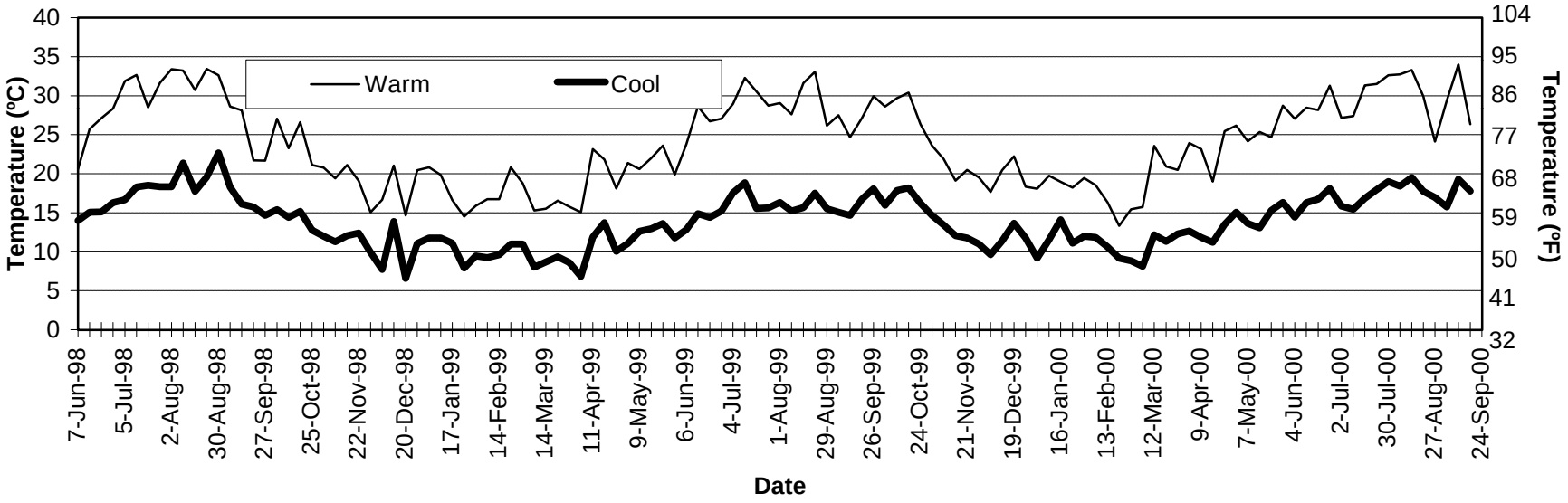


Figure 2b. Weekly mean warm [1200 HR to 1600 HR (12 noon to 4 p.m.)] and cool [0200 HR to 0600 HR (2 a.m. to 6 a.m.)] **soil temperatures** [at a 5.1-cm (2-inch) depth] on-site at Industry Hills Golf Courses, Industry, Calif., from 7 June 1998 to 23 Sept. 2000.

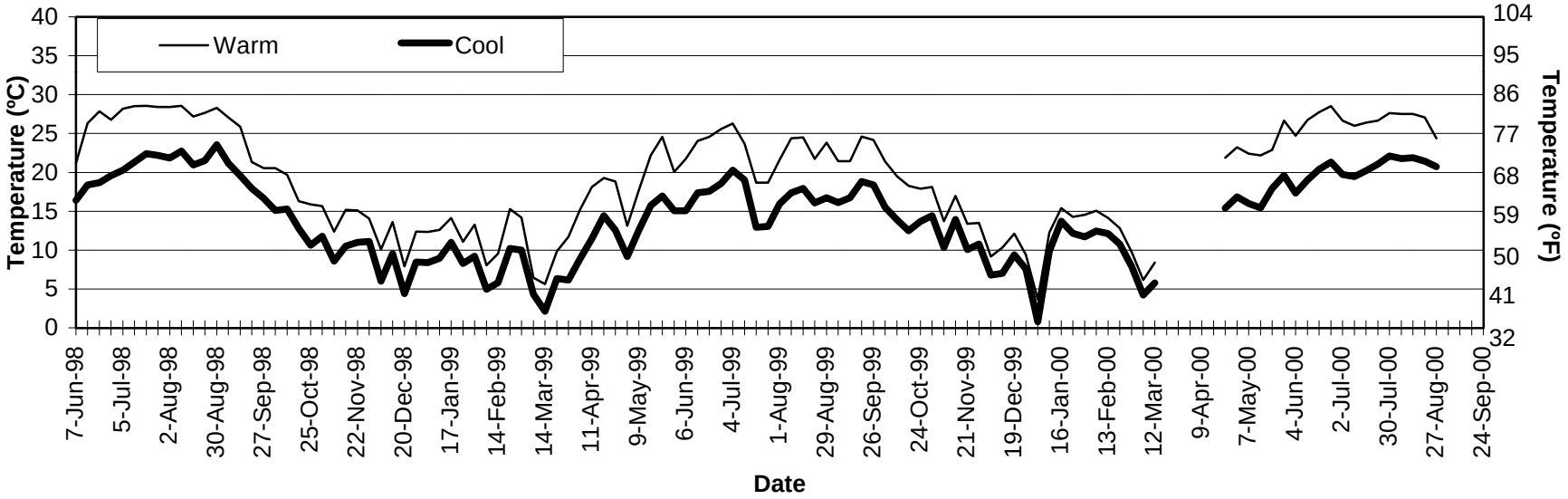
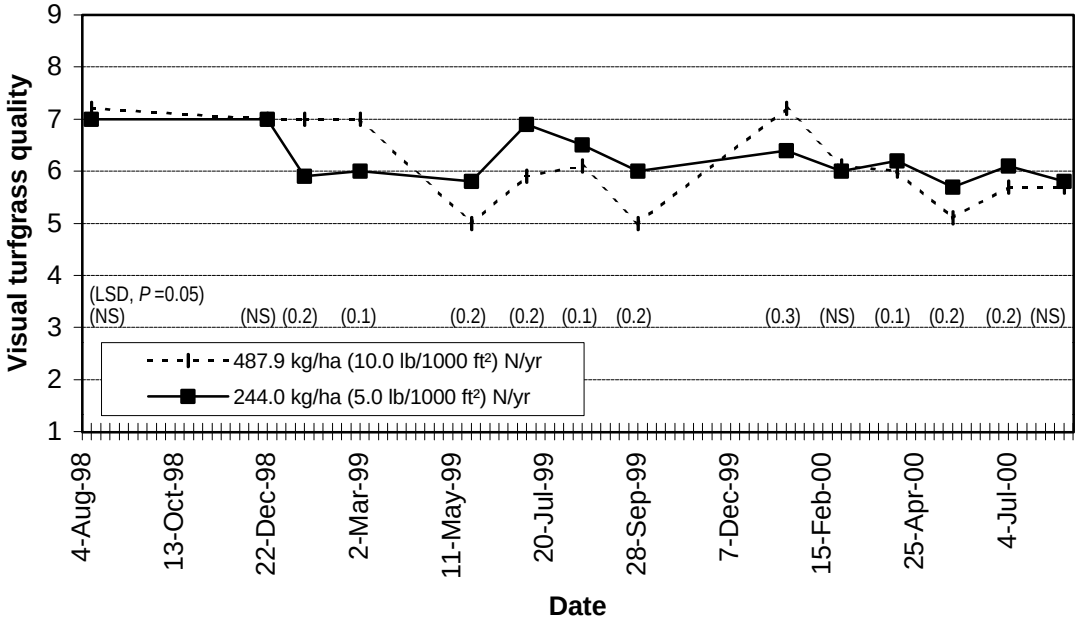


Figure 3. The effect of N treatments on visual turfgrass quality (1 to 9 scale, with 1=worst, 5=minimally acceptable, and 9=best quality putting green) of an annual bluegrass putting green from 12 Aug. 1998 to 18 Aug. 2000.



Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K, Fe, and culitvation treatments basically did not affect visual turfgrass quality; Fe had a minimal effect.

Table 7. The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on visual turfgrass putting green quality (1 to 9 scale, with 1=worst, 5=minimally acceptable, and 9=best quality putting green) of an annual bluegrass putting green from 12 Aug. 1998 to 18 Aug. 2000.

	Visual turfgrass quality													
	Date													
Treatments	12 Aug. 1998	22 Dec. 1998	19 Jan. 1999	2 Mar. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	18 Jan. 2000	29 Feb. 2000	11 Apr. 2000	23 May 2000	5 July 2000	18 Aug. 2000
Cultivation level treatments[z]														
No cultivation	7.0[y]	7.0	6.4	6.5	5.3	6.4	6.3	5.5	6.8	6.0	6.1	5.5	5.9	5.8
With cultivation	7.2	7.0	6.4	6.5	5.4	6.4	6.3	5.5	6.8	6.0	6.1	5.3	5.9	5.7
LSD, P=0.05	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]														
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	7.2	7.0	7.0	7.0	5.0	5.9	6.1	5.0	7.2	6.1	6.0	5.1	5.7	5.7
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	7.0	7.0	5.9	6.0	5.8	6.9	6.5	6.0	6.4	6.0	6.2	5.7	6.1	5.8
LSD, P=0.05	NS	.	0.2	0.1	0.2	0.2	0.1	0.2	0.3	NS	0.1	0.2	0.2	NS
K_2O-fertility rate treatments[x]														
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	7.2	7.0	6.4	6.4	5.4	6.4	6.4	5.5	6.6	6.0	6.1	5.5	5.9	5.8
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	7.0	7.0	6.5	6.5	5.4	6.4	6.2	5.4	6.9	6.0	6.1	5.3	5.9	5.7
LSD, P=0.05	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.2	NS	NS
$FeSO_4$ level treatments[w]														
With $FeSO_4$	7.2	7.0	6.5	6.5	5.4	6.5	6.4	5.5	7.2	6.0	6.1	5.5	5.9	5.8
No $FeSO_4$	7.0	7.0	6.3	6.5	5.3	6.3	6.3	5.5	6.3	6.0	6.1	5.3	5.9	5.7
LSD, P=0.05	NS	.	NS	NS	NS	0.2	NS	NS	0.3	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]														
Nitrogen (N)	NS	.	***	***	***	***	***	***	***	NS	***	***	***	NS
Potassium (K)	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
N x K	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	.	NS	NS	NS	*	NS	NS	***	NS	NS	NS	NS	NS
N x Fe	NS	.	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
K x Fe	NS	.	NS	NS	NS	*	NS	NS	NS	NS	**	NS	NS	NS
N x K x Fe	NS	.	*	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
Cultivation (C)	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
C x K	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x Fe	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x Fe	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K x Fe	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K x Fe	NS	.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]

[v]Strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table 8**.** The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on overall visual turfgrass putting green quality (1 to 9 scale, with 1=worst, 5=minimally acceptable, and 9=best quality putting green), overall visual turfgrass color (1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest green), and overall percent coverage of seedheads of an annual bluegrass putting green from 1998 to 2000.

Treatments	Overall visual turfgrass quality	Overall visual turfgrass color	Overall seedhead coverage (%)
Cultivation level treatments[z]			
No cultivation	6.2[y]	6.5	24
With cultivation	6.2	6.5	25
LSD, *P*=0.05	NS	NS	NS
N-fertility rate treatments[x]			
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	6.1	6.8	33
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	6.2	6.3	16
LSD, *P*=0.05	0.04	0.1	4
K_2O-fertility rate treatments[x]			
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	6.2	6.5	24
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	6.2	6.6	25
LSD, *P*=0.05	NS	NS	NS
$FeSO_4$ level treatments[w]			
With $FeSO_4$	6.2	6.7	23
No $FeSO_4$	6.1	6.4	26
LSD, *P*=0.05	0.04	0.1	NS
Summary of ANOVA effects[v]			
Nitrogen (N)	***	***	***
Potassium (K)	NS	NS	NS
N x K	NS	NS	NS
Iron (Fe)	***	***	NS
N x Fe	*	NS	NS
K x Fe	NS	*	NS
N x K x Fe	NS	NS	NS
Cultivation (C)	NS	NS	NS
C x N	NS	NS	NS
C x K	NS	NS	NS
C x N x K	NS	NS	NS
C x Fe	*	NS	NS
C x N x Fe	NS	NS	NS
C x K x Fe	*	NS	NS
C x N x K x Fe	NS	NS	NS
Date (D)	***	***	***
C x D	*	NS	NS
N x D	***	***	***
K x D	*	NS	NS
N x K x D	NS	*	NS
Fe x D	***	***	NS
N x Fe x D	NS	NS	NS
K x Fe x D	NS	NS	*
N x K x Fe x D	NS	NS	NS
C x N x D	*	*	NS
C x K x D	NS	NS	NS
C x N x K x D	NS	*	*
C x Fe x D	NS	NS	NS
C x N x Fe x D	NS	NS	NS
C x K x Fe x D	NS	NS	NS
C x N x K x Fe x D	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

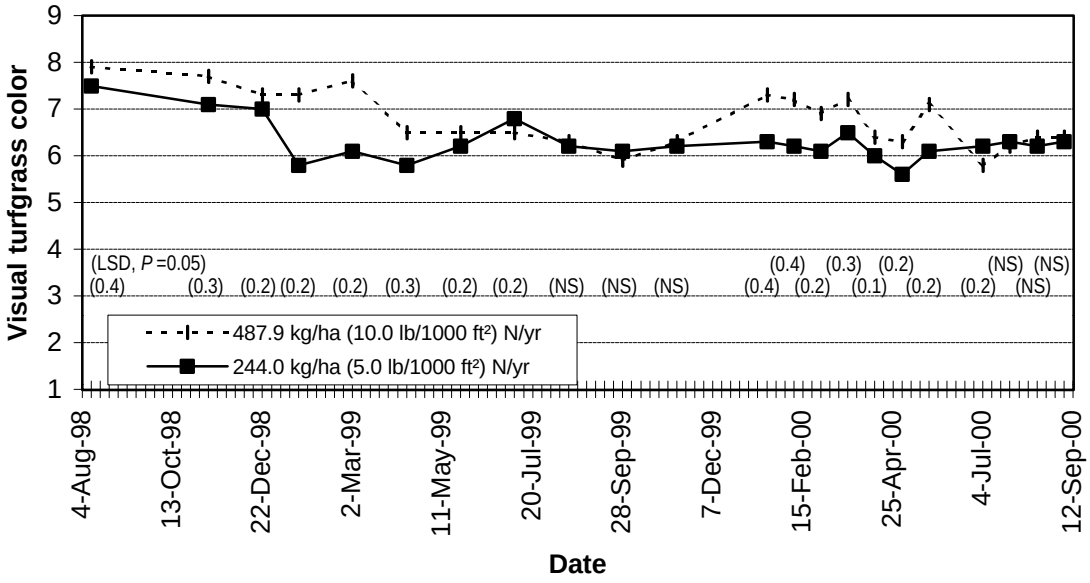
[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

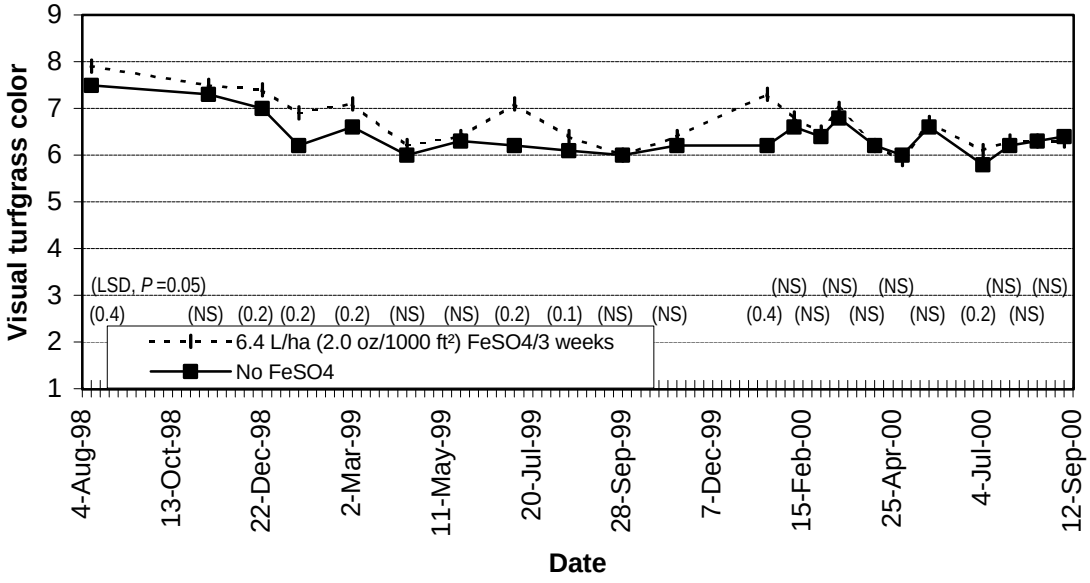
[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Overall ANOVA via repeated measures, with date as the repeated measures factor [by date analyses via strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor].

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 4. The effect of N and Fe treatments on visual turfgrass color (1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest green) of an annual bluegrass putting green from 12 Aug. 1998 to 5 Sept. 2000.





Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K and culitvation treatments did not affect visual turfgrass color.

Table 9. The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on visual turfgrass color (1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest green) of an annual bluegrass putting green from 12 Aug. 1998 to 5 Sept. 2000.

	Visual turfgrass color																					
	Date																					
Treatments	12 Aug. 1998	10 Nov. 1998	22 Dec. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	9 Feb. 2000	29 Feb. 2000	22 Mar. 2000	11 Apr. 2000	3 May 2000	23 May 2000	5 July 2000	25 July 2000	18 Aug. 2000	5 Sept. 2000
Cultivation level treatments[z]																						
No cultivation	7.5[y]	7.3	7.1	6.5	6.9	6.2	6.4	6.7	6.2	6.0	6.2	6.8	6.7	6.5	6.8	6.2	6.0	6.7	6.0	6.2	6.3	6.4
With cultivation	7.8	7.5	7.2	6.6	6.8	6.1	6.4	6.6	6.3	6.0	6.3	6.8	6.7	6.5	6.9	6.2	5.9	6.6	6.0	6.2	6.3	6.4
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]																						
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	7.9	7.7	7.3	7.3	7.6	6.5	6.5	6.5	6.3	5.9	6.3	7.3	7.2	6.9	7.2	6.4	6.3	7.1	5.8	6.2	6.4	6.4
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	7.5	7.1	7.0	5.8	6.1	5.8	6.2	6.8	6.2	6.1	6.2	6.3	6.2	6.1	6.5	6.0	5.6	6.1	6.2	6.3	6.2	6.3
LSD, P=0.05	0.4	0.3	0.2	0.2	0.2	0.3	0.2	0.2	NS	NS	NS	0.4	0.4	0.2	0.3	0.1	0.2	0.2	0.2	NS	NS	NS
K_2O-fertility rate treatments[x]																						
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	7.8	7.3	7.2	6.5	6.8	6.2	6.4	6.8	6.3	5.9	6.2	6.7	6.5	6.5	6.9	6.2	5.9	6.7	5.9	6.2	6.3	6.4
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	7.5	7.5	7.2	6.6	6.9	6.1	6.4	6.6	6.2	6.1	6.3	6.9	6.9	6.5	6.9	6.2	5.9	6.6	6.1	6.3	6.3	6.3
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																						
With $FeSO_4$	7.9	7.5	7.4	6.9	7.1	6.2	6.4	7.1	6.4	6.0	6.4	7.3	6.8	6.5	7.0	6.2	5.9	6.7	6.1	6.3	6.3	6.3
No $FeSO_4$	7.5	7.3	7.0	6.2	6.6	6.0	6.3	6.2	6.1	6.0	6.2	6.2	6.6	6.4	6.8	6.2	6.0	6.6	5.8	6.2	6.3	6.4
LSD, P=0.05	0.4	NS	0.2	0.2	0.2	NS	NS	0.2	0.1	NS	NS	0.4	NS	NS	NS	NS	NS	NS	0.2	NS	NS	NS
Summary of ANOVA effects[v]																						
Nitrogen (N)	*	***	***	***	***	***	**	**	NS	NS	NS	***	***	***	***	***	***	***	**	NS	NS	NS
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	*	NS	***	***	**	NS	NS	***	***	NS	NS	***	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivation (C)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*
C x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K	NS	NS	NS	NS	**	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K x Fe	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

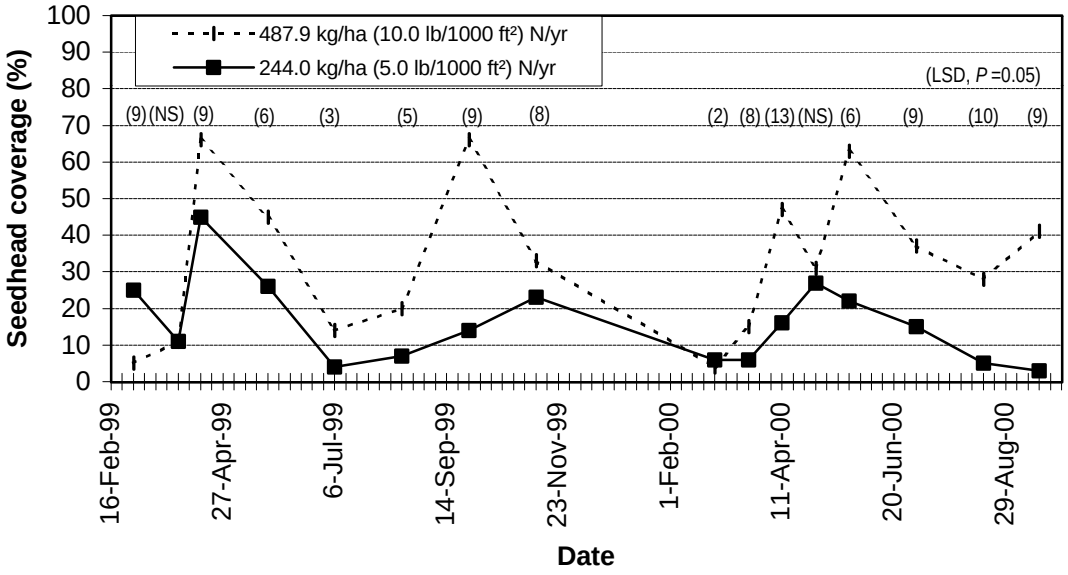
[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 5. The effect of N treatments on percent coverage of seedheads of an annual bluegrass putting green from 2 Mar. 1999 to 19 Sept. 2000.



Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K, Fe, and culitvation treatments basically did not affect percent coverage of seedheads.

Table 10. The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on percent coverage of seedheads of an annual bluegrass putting green from 2 Mar. 1999 to 19 Sept. 2000.

	Seedhead coverage (%)															
	Date															
Treatments	2 Mar. 1999	31 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	29 Feb. 2000	22 Mar. 2000	11 Apr. 2000	3 May 2000	23 May 2000	5 July 2000	18 Aug. 2000	19 Sept. 2000
Cultivation level treatments[z]																
No cultivation	14[y]	11	52	35	8	13	40	29	5	9	32	29	43	26	18	20
With cultivation	15	11	59	36	10	14	39	27	5	12	31	28	43	27	15	23
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]																
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	5	11	66	45	14	20	66	33	4	15	47	31	63	37	28	41
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	25	11	45	26	4	7	14	23	6	6	16	27	22	15	5	3
LSD, P=0.05	9	NS	9	6	3	5	9	8	2	8	13	NS	6	9	10	9
K_2O-fertility rate treatments[x]																
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	14	10	50	33	9	13	39	29	5	9	34	28	42	27	19	21
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	15	12	61	38	9	14	41	27	5	12	30	29	44	26	14	22
LSD, P=0.05	NS	NS	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																
With $FeSO_4$	16	11	54	34	7	12	40	25	5	10	33	27	40	22	17	18
No $FeSO_4$	13	11	56	37	11	15	40	32	5	11	31	30	46	31	16	25
LSD, P=0.05	NS	NS	NS	NS	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]																
Nitrogen (N)	***	NS	***	***	***	***	***	*	*	*	***	NS	***	***	***	***
Potassium (K)	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivation (C)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	**	NS	*	*
C x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
C x K x Fe	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

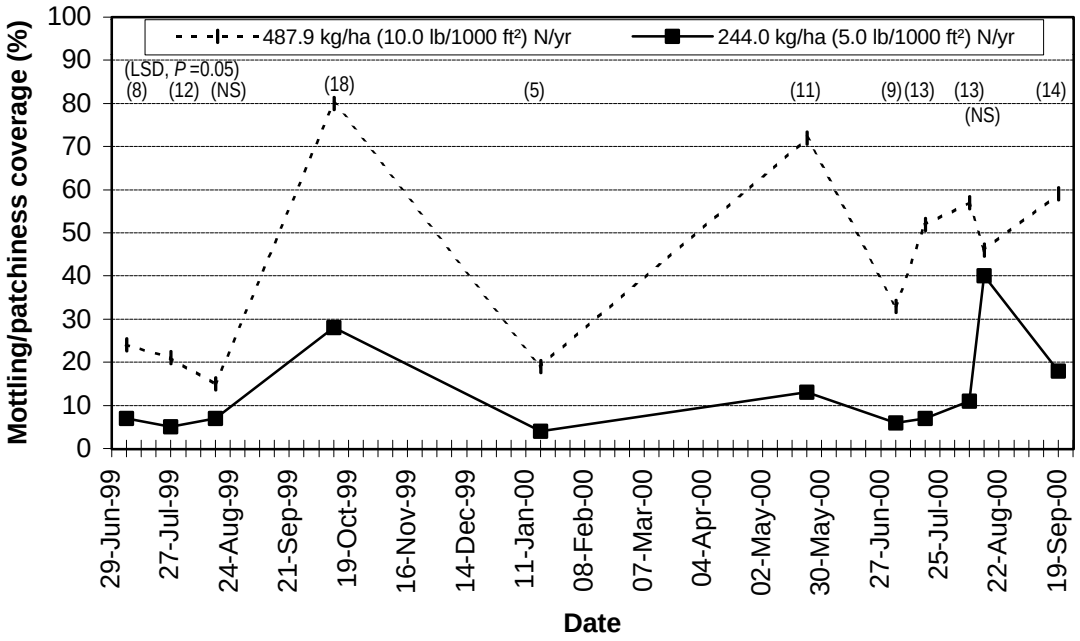
[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 6. The effect of N treatments on percent coverage of mottling/patchiness of an annual bluegrass putting green from 6 July 1999 to 19 Sept. 2000.



Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K, Fe, and culitvation treatments basically did not affect percent coverage of mottling/patchiness.

Table 11. The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on percent coverage of mottling/patchiness of an annual bluegrass putting green from 6 July 1999 to 19 Sept. 2000.

	Mottling/patchiness (% coverage)										
	Date										
Treatments	6 July 1999	30 July 1999	17 Aug. 1999	12 Oct. 1999	18 Jan. 2000	23 May 2000	5 July 2000	19 July 2000	9 Aug. 2000	18 Aug. 2000	19 Sept. 2000
Cultivation level treatments[z]											
No cultivation	17[y]	16	12	54	12	40	21	33	35	40	39
With cultivation	14	10	9	54	11	45	18	26	33	45	38
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]											
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	24	21	15	80	19	72	33	52	57	46	59
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	7	5	7	28	4	13	6	7	11	40	18
LSD, P=0.05	8	12	NS	18	5	11	9	13	13	NS	14
K_2O-fertility rate treatments[x]											
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	17	14	11	51	14	43	20	29	30	41	34
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	14	12	10	57	9	42	20	30	38	44	43
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]											
With $FeSO_4$	13	11	9	56	6	38	21	26	32	42	41
No $FeSO_4$	18	15	12	52	18	47	18	33	36	44	36
LSD, P=0.05	NS	NS	NS	NS	5	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]											
Nitrogen (N)	***	**	NS	***	***	***	***	***	***	NS	***
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	***	*	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	**	NS	NS	NS	*	NS	NS
Cultivation (C)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K	*	NS	*	*	NS	NS	NS	NS	NS	NS	NS
C x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
C x N x K x Fe	NS	NS	NS	*	NS	*	NS	NS	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

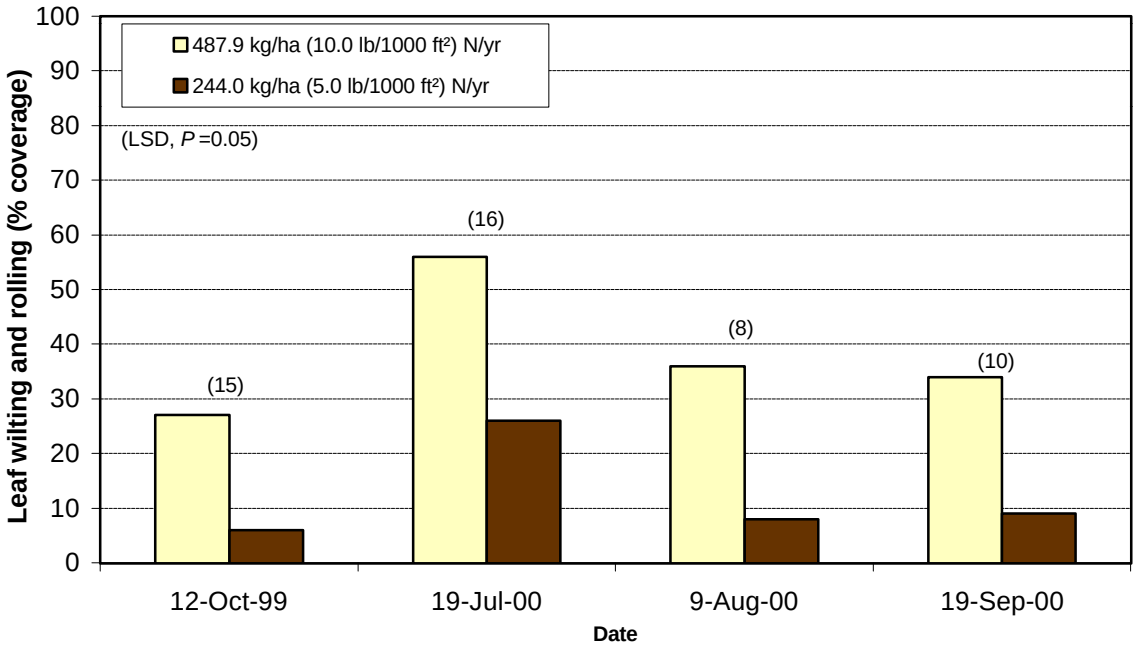
[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

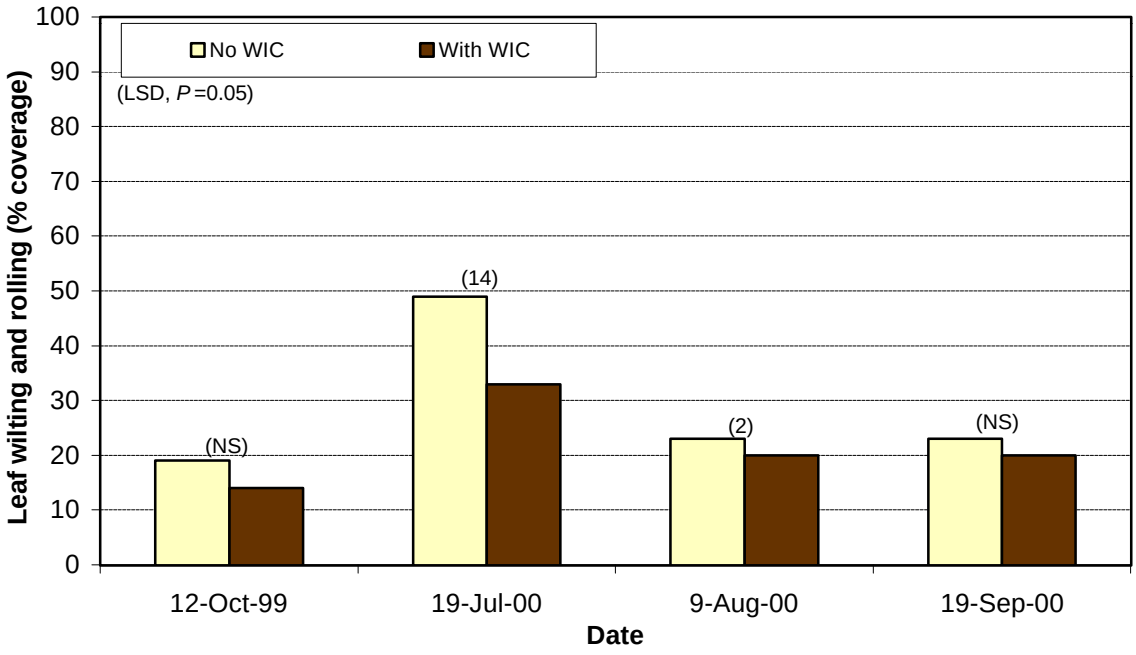
[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[x]Strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 7. The effect of N and water injection cultivation treatments on percent coverage of leaf wilting and rolling of an annual bluegrass putting green in 1999 and 2000.





Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K and Fe treatments did not affect percent coverage of leaf wilting and rolling.

Table 12**.** The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on coverage of cool-season brown patch, leaf wilting and rolling, and scalping of an annual bluegrass putting green from 28 May 1999 to 26 Sept. 2000.

	Cool-season brown patch		Leaf wilting and rolling				Scalping		
	Date		Date				Date		
Treatments	28 May 1999	30 July 1999	12 Oct. 1999	19 July 2000	9 Aug. 2000	19 Sept. 2000	5 July 2000	18 Aug. 2000	26 Sept. 2000
	% coverage								
Cultivation level treatments[z]									
No cultivation	2.2[y]	0.8	19	49	23	23	3	6	7
With cultivation	2.2	2.9	14	33	20	20	1	11	11
LSD, P=0.05	NS	NS	NS	14	2	NS	NS	NS	NS
N-fertility rate treatments[x]									
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	1.4	0.8	27	56	36	34	3	12	15
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	2.9	2.9	6	26	8	9	0	6	3
LSD, P=0.05	1.0	NS	15	16	8	10	2	NS	8
K_2O-fertility rate treatments[x]									
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	2.0	2.6	14	43	19	17	2	7	9
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	2.4	1.1	19	39	25	26	1	11	9
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]									
With $FeSO_4$	2.2	1.2	19	45	21	24	3	11	11
No $FeSO_4$	2.1	2.5	14	37	22	18	1	7	7
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]									
Nitrogen (N)	**	NS	**	***	***	***	**	NS	**
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	*	*	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	*	NS	NS	NS	NS
Cultivation (C)	NS	NS	NS	*	*	NS	NS	NS	NS
C x N	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

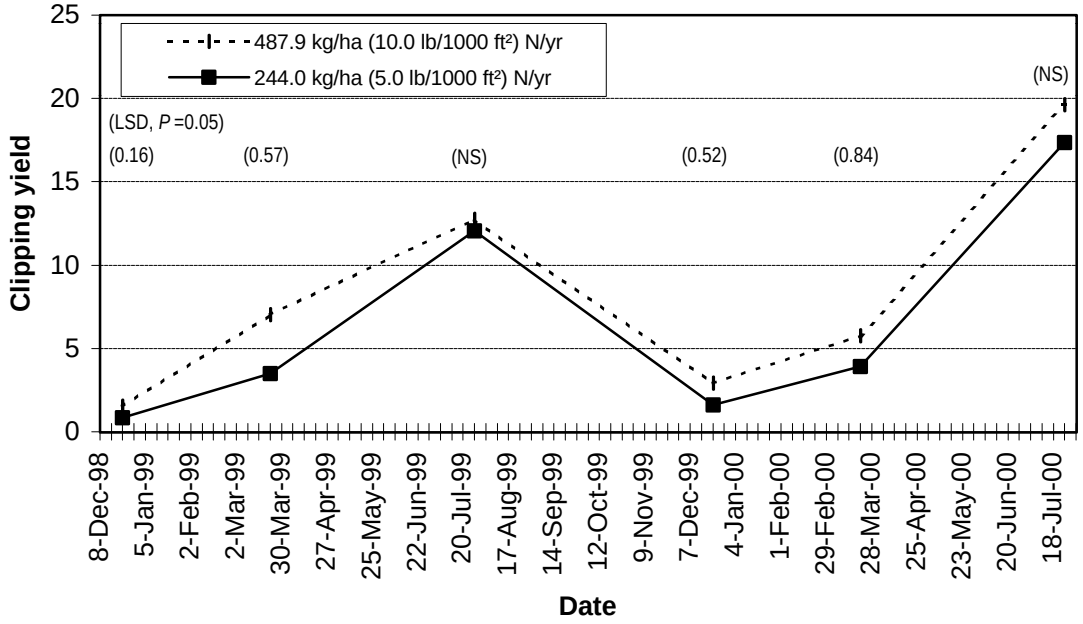
[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[x]Strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 8. The effect of N treatments on clipping yields [g dry clippings/2.0 m² (22.0 ft²) per 1 d] of an annual bluegrass putting green from 21 Dec. 1998 to 26 July 2000.



Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K and Fe treatments did not affect clipping yield. Since data were collected from main plots, the cultivation effect could not be tested.

Table 13. The effect of N, K_2O, and $FeSO_4$ treatments on clipping yield [g dry clippings/2.0 m^2 (22.0 ft^2) per 1 d] of an annual bluegrass putting green from 21 Dec. 1998 to 26 July 2000.

	Clipping yield[z]					
	Date					
Treatments	21 Dec. 1998	23 Mar. 1999	30 July 1999	21 Dec. 1999	22 Mar. 2000	26 July 2000
N-fertility rate treatments[y]						
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	1.53[x]	7.01	12.74	2.92	5.77	19.61
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	0.83	3.49	12.04	1.63	3.93	17.34
LSD, P=0.05	0.16	0.57	NS	0.52	0.84	NS
K_2O-fertility rate treatments[y]						
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	1.19	5.16	12.31	2.27	4.99	18.55
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	1.13	5.33	12.45	2.28	4.71	18.39
LSD, P=0.05	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]						
With $FeSO_4$	1.13	5.35	13.14	2.46	4.94	18.34
No $FeSO_4$	1.18	5.14	11.66	2.09	4.76	18.60
LSD, P=0.05	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]						
Nitrogen (N)	***	***	NS	***	***	NS
Potassium (K)	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS
N x Fe	NS	*	NS	NS	NS	NS
K x Fe	NS	NS	*	NS	*	NS
N x K x Fe	NS	NS	NS	NS	NS	NS

[z]Clipping yield samples represent 66% of the total surface area of the main plot. Mowing height for 21 Dec. 1998, 23 Mar. 1999, and 30 July 1999 = 3.96 mm (0.156 inch); 21 Dec. 1999 = 3.30 mm (0.130 inch); and 22 Mar. 2000 and 26 July 2000 = 3.81 mm (0.150 inch).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

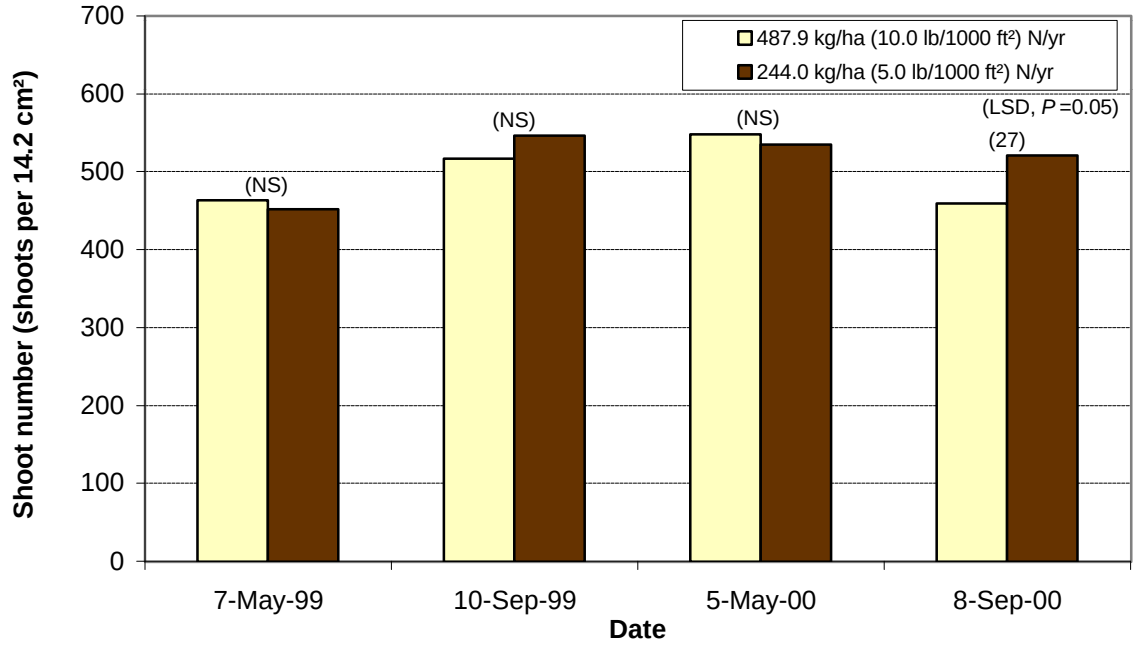
[x]Mean separation with Fisher's Protected LSD test.

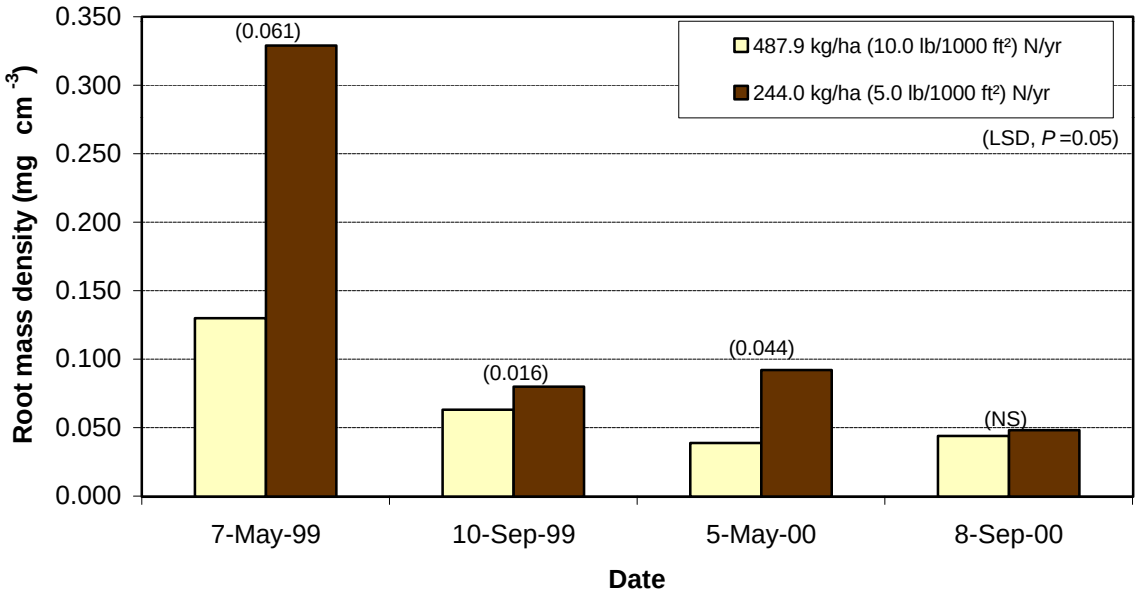
[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 9. The effect of N treatments on shoot number (shoots per 14.2 cm²) and root mass density (mg cm^{-3}) in the 1.3- to 8.9-cm (0.5- to 3.5-inch) deep root zone of an annual bluegrass putting green in 1999 and 2000.





Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: N, K, Fe, and cultivation treatments basically did not affect shoot number; K, Fe, and cultivation treatments basically did not affect root mass density.

Table 14. The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on shoot number and root mass density of an annual bluegrass putting green as determined by samples taken in 1999 and 2000.

	Shoot number (shoots per 14.2 cm^2)				Root mass density ($mg \cdot cm^{-3}$)			
	Date				Date			
Treatments	7 May 1999	10 Sept. 1999	5 May 2000	8 Sept. 2000	7 May 1999	10 Sept. 1999	5 May 2000	8 Sept. 2000
Cultivation level treatments[z]								
No cultivation	456[y]	542	551	492	0.234[y]	0.070	0.044	0.046
With cultivation	459	522	532	489	0.225	0.073	0.086	0.046
LSD, P=0.05	NS	NS	NS	NS	NS	0.003	NS	NS
N-fertility rate treatments[x]								
487.9 $kg \cdot ha^{-1}$ (10.0 lb/1000 ft^2) N/yr	463	517	548	459	0.130	0.063	0.039	0.044
244.0 $kg \cdot ha^{-1}$ (5.0 lb/1000 ft^2) N/yr	452	546	535	521	0.329	0.080	0.092	0.048
LSD, P=0.05	NS	NS	NS	27	0.061	0.016	0.044	NS
K_2O-fertility rate treatments[x]								
585.5 $kg \cdot ha^{-1}$ (12.0 lb/1000 ft^2) K_2O/yr	462	525	530	509	0.225	0.074	0.061	0.046
195.2 $kg \cdot ha^{-1}$ (4.0 lb/1000 ft^2) K_2O/yr	453	538	553	472	0.234	0.069	0.069	0.046
LSD, P=0.05	NS	NS	NS	27	NS	NS	NS	NS
$FeSO_4$ level treatments[w]								
With $FeSO_4$	450	545	538	469	0.226	0.065	0.064	0.041
No $FeSO_4$	465	519	545	511	0.233	0.078	0.066	0.051
LSD, P=0.05	NS	NS	NS	27	NS	NS	NS	NS
Summary of ANOVA effects[v]								
Nitrogen (N)	NS	NS	NS	***	***	*	*	NS
Potassium (K)	NS	NS	NS	**	NS	NS	NS	NS
N x K	*	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	**	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS
Cultivation (C)	NS	NS	NS	NS	NS	*	NS	NS
C x N	NS	NS	NS	NS	NS	NS	NS	NS
C x K	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K	NS	NS	NS	NS	NS	NS	NS	NS
C x Fe	NS	NS	NS	NS	NS	NS	NS	NS
C x N x Fe	NS	NS	NS	NS	*	NS	NS	NS
C x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K x Fe	NS	NS	*	NS	NS	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 $L \cdot ha^{-1}$ (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 $kg \cdot ha^{-1}$ (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 $kg \cdot ha^{-1}$ $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 $L \cdot ha^{-1}$ (2.1 gal/1000 ft^2)].

[v]Strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table 15. The effect of water injection cultivation, N, K_2O, and $FeSO_4$ treatments on root mass, crown mass, and total plant mass of an annual bluegrass putting green as determined by samples taken in 1999 and 2000.

	Root mass (g per 108.0 cm^3)			Crown mass (g per 14.2 cm^2)			Total plant mass (g) (root + crown mass)		
	Date			Date			Date		
Treatments	10 Sept. 1999	5 May 2000	8 Sept. 2000	10 Sept. 1999	5 May 2000	8 Sept. 2000	10 Sept. 1999	5 May 2000	8 Sept. 2000
Cultivation level treatments[z]									
No cultivation	0.0075	0.0047	0.0049	0.5693	0.7800	0.6510	0.5769	0.7847	0.6559
With cultivation	0.0079	0.0093	0.0050	0.5592	0.7365	0.6466	0.5672	0.7459	0.6516
LSD, P=0.05	0.0003	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]									
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	0.0068	0.0042	0.0047	0.5122	0.6843	0.5716	0.5190	0.6885	0.5763
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	0.0086	0.0099	0.0052	0.6164	0.8323	0.7260	0.6250	0.8422	0.7312
LSD, P=0.05	0.0017	0.0048	NS	0.0351	0.0277	0.0482	0.0357	0.0276	0.0487
K_2O-fertility rate treatments[x]									
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	0.0080	0.0066	0.0049	0.5372	0.7672	0.6510	0.5452	0.7738	0.6560
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	0.0075	0.0075	0.0050	0.5913	0.7493	0.6465	0.5988	0.7568	0.6516
LSD, P=0.05	NS	NS	NS	0.0351	NS	NS	0.0357	NS	NS
$FeSO_4$ level treatments[w]									
With $FeSO_4$	0.0071	0.0069	0.0044	0.5407	0.7528	0.6705	0.5478	0.7597	0.6749
No $FeSO_4$	0.0084	0.0072	0.0055	0.5879	0.7638	0.6271	0.5963	0.7710	0.6326
LSD, P=0.05	NS	NS	NS	0.0351	NS	NS	0.0357	NS	NS
Summary of ANOVA effects[v]									
Nitrogen (N)	*	*	NS	***	***	***	***	***	***
Potassium (K)	NS	NS	NS	**	NS	NS	**	NS	NS
N x K	NS	NS	NS	NS	*	NS	NS	*	NS
Iron (Fe)	NS	NS	NS	**	NS	NS	**	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivation (C)	*	NS	NS	NS	NS	NS	NS	NS	NS
C x N	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x Fe	NS	NS	NS	**	NS	NS	**	NS	NS
C x N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Cultivation with Toro HydroJect 3000, #53 nozzles (11 operating), run in the raised (transport) position and set to second greatest hole density. In 1998, applied once every 4 weeks from June through October; in 1999, applied once every 3 weeks from May through October; and in 2000, applied once every 3 weeks from April through September.

[y]Mean separation with Fisher's Protected LSD test.

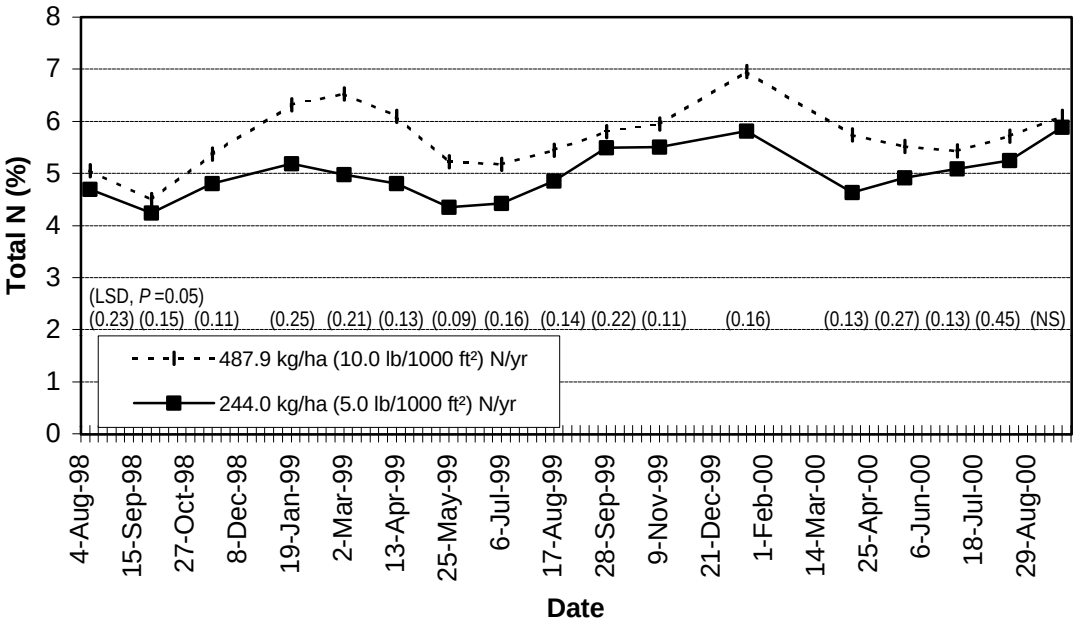
[x]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N- P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Strip-plot design: N, K, Fe treatments were the main plot factor (2x2x2 factorial) and cultivation treatments were the subplot factor.

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 10. The effect of N treatments on total nitrogen content of clippings of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.



Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K and Fe treatments basically did not affect total N content of clippings. Since clippings were collected from main plots, the cultivation effect could not be tested.

Note: A published target range for total nitrogen content of clippings of an annual bluegrass putting green could not be located. A target range of 4.5% to 6.0% total N was cited for creeping bentgrass [Nuss, J. 1994. Golf course management 62(2):120–128].

Table 16. The effect of N, K_2O, and $FeSO_4$ treatments on clipping nitrogen content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total N (%)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	5.05[x]	4.50	5.37	6.32	6.52	6.09	5.22	5.17	5.44	5.80	5.95	6.96	5.74	5.52	5.43	5.71	6.10
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	4.70	4.24	4.81	5.18	4.98	4.80	4.35	4.43	4.85	5.49	5.51	5.81	4.63	4.92	5.09	5.25	5.89
LSD, P=0.05	0.23	0.15	0.11	0.25	0.21	0.13	0.09	0.16	0.14	0.22	0.11	0.16	0.13	0.27	0.13	0.45	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	4.93	4.39	5.05	5.74	5.86	5.48	4.77	4.84	5.20	5.74	5.71	6.30	5.13	5.21	5.22	5.36	6.00
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	4.82	4.35	5.12	5.80	5.80	5.40	4.79	4.76	5.09	5.55	5.75	6.47	5.25	5.19	5.29	5.59	5.97
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.16	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	4.88	4.34	5.15	5.85	5.86	5.48	4.79	4.85	5.17	5.64	5.70	6.48	5.18	5.21	5.21	5.50	5.80
No $FeSO_4$	4.87	4.40	5.02	5.69	5.80	5.41	4.78	4.74	5.12	5.66	5.76	6.28	5.19	5.19	5.30	5.43	6.16
LSD, P=0.05	NS	NS	0.11	NS	NS	NS	NS	NS	NS	NS	NS	0.16	NS	NS	NS	NS	0.28
Summary of ANOVA effects[v]																	
Nitrogen (N)	**	***	***	***	***	***	***	***	***	**	***	***	***	***	***	*	NS
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	**
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Calculated on a dry weight basis and determined by combustion gas analyzer method (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

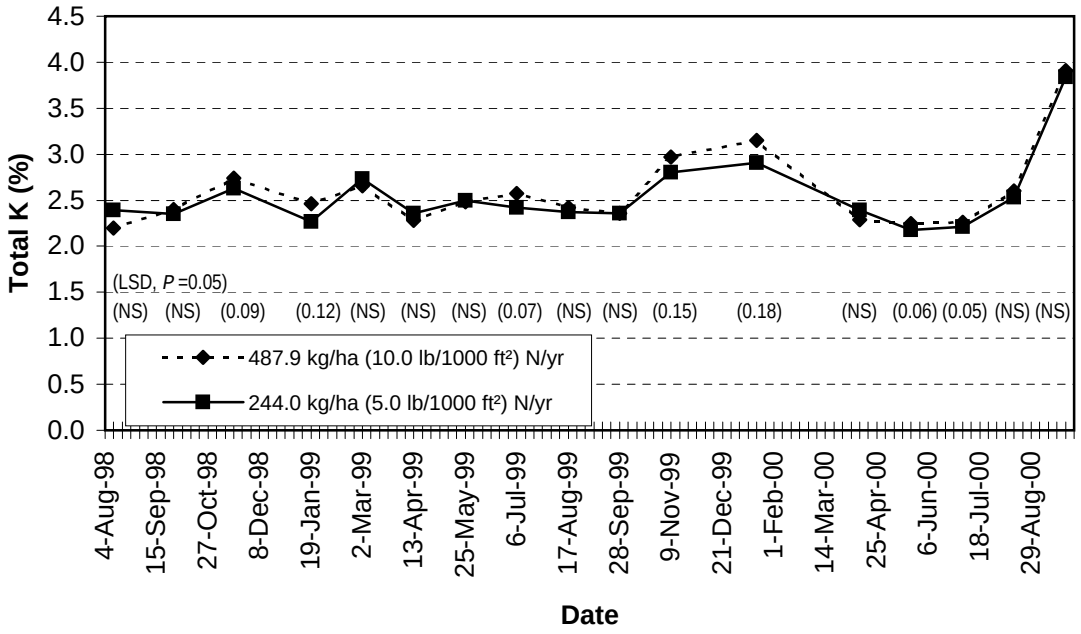
[x]Mean separation with Fisher's Protected LSD test.

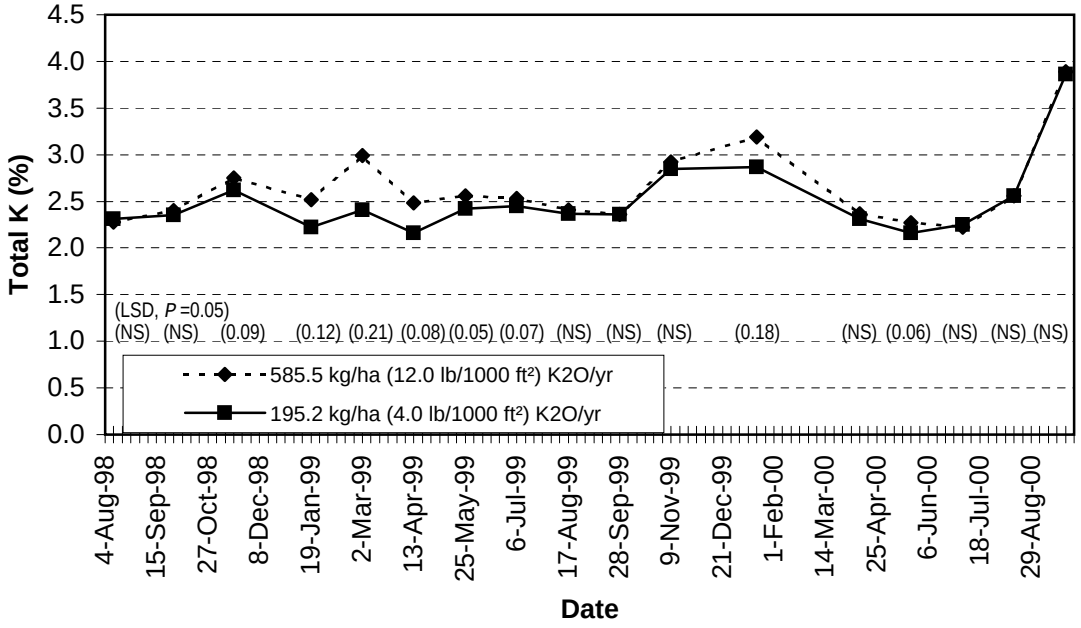
[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 11. The effect of N and K treatments on total potassium content of clippings of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.





Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: Fe treatments basically did not affect total K content of clippings. Since clippings were collected from main plots, the cultivation effect could not be tested.

Note: A published target range for total potassium content of clippings of an annual bluegrass putting putting green could not be located. A target range of 2.2% to 2.6% total K was cited for creeping bentgrass [Nuss, J. 1994. Golf course management 62(2):120–128].

Table 17. The effect of N, K_2O, and $FeSO_4$ treatments on clipping potassium content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total K (%)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	2.20[x]	2.40	2.74	2.46	2.66	2.28	2.48	2.57	2.42	2.36	2.97	3.15	2.29	2.25	2.26	2.60	3.91
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	2.39	2.35	2.63	2.27	2.73	2.36	2.50	2.42	2.37	2.36	2.80	2.91	2.39	2.18	2.21	2.53	3.84
LSD, P=0.05	NS	NS	0.09	0.12	NS	NS	NS	0.07	NS	NS	0.15	0.18	NS	0.06	0.05	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	2.28	2.40	2.75	2.52	2.99	2.48	2.56	2.53	2.41	2.36	2.92	3.19	2.37	2.27	2.22	2.56	3.89
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	2.31	2.35	2.62	2.22	2.41	2.16	2.42	2.45	2.37	2.36	2.85	2.87	2.31	2.16	2.25	2.56	3.86
LSD, P=0.05	NS	NS	0.09	0.12	0.21	0.08	0.05	0.07	NS	NS	NS	0.18	NS	0.06	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	2.43	2.38	2.69	2.41	2.78	2.32	2.48	2.48	2.39	2.36	2.88	3.06	2.38	2.23	2.23	2.54	3.87
No $FeSO_4$	2.16	2.37	2.68	2.32	2.61	2.33	2.50	2.51	2.39	2.36	2.89	3.00	2.30	2.20	2.24	2.58	3.88
LSD, P=0.05	0.23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	*	**	NS	NS	NS	***	NS	NS	*	**	NS	*	*	NS	NS
Potassium (K)	NS	NS	**	***	***	***	***	*	NS	NS	NS	**	NS	**	NS	NS	NS
N x K	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Iron (Fe)	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Calculated on a dry weight basis and determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

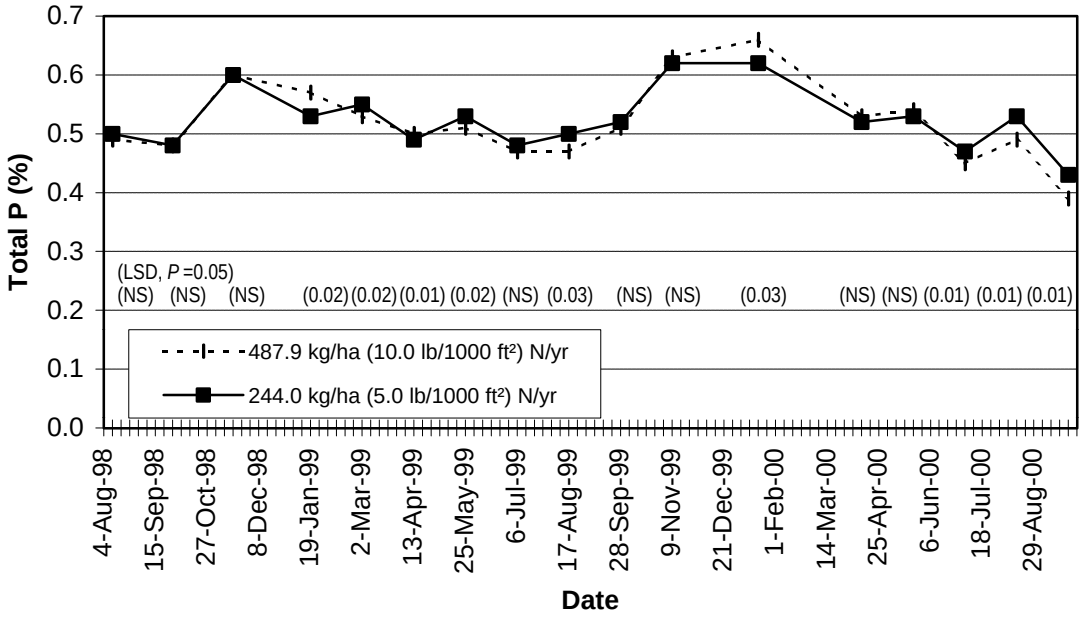
[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 12. The effect of N treatments on total phosphorus content of clippings of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.



Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K and Fe treatments basically did not affect total P content of clippings. Since clippings were collected from main plots, the cultivation effect could not be tested.

Note: A published target range for total phosphorus content of clippings of an annual bluegrass putting putting green could not be located. A target range of 0.3% to 0.6% total P was cited for creeping bentgrass [Nuss, J. 1994. Golf course management 62(2):120–128].

Table 18. The effect of N, K_2O, and $FeSO_4$ treatments on clipping phosphorus content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total P (%)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	0.49[x]	0.48	0.60	0.57	0.53	0.50	0.51	0.47	0.47	0.51	0.63	0.66	0.53	0.54	0.45	0.49	0.39
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	0.50	0.48	0.60	0.53	0.55	0.49	0.53	0.48	0.50	0.52	0.62	0.62	0.52	0.53	0.47	0.53	0.43
LSD, P=0.05	NS	NS	NS	0.02	0.02	0.01	0.02	NS	0.03	NS	NS	0.03	NS	NS	0.01	0.01	0.01
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	0.50	0.48	0.60	0.55	0.54	0.49	052	0.48	0.48	0.52	0.62	0.64	0.52	0.54	0.46	0.51	0.41
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	0.49	0.48	0.60	0.55	0.54	0.49	0.52	0.47	0.48	0.52	0.63	0.64	0.53	0.53	0.46	0.51	0.41
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	0.51	0.48	0.60	0.56	0.54	0.50	0.51	0.47	0.48	0.52	0.62	0.65	0.53	0.53	0.45	0.51	0.40
No $FeSO_4$	0.48	0.48	0.60	0.54	0.54	0.49	0.52	0.49	0.49	0.52	0.63	0.63	0.52	0.53	0.46	0.52	0.42
LSD, P=0.05	0.03	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.01	NS	0.01
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	***	*	**	*	NS	*	NS	NS	*	NS	NS	***	***	***
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	**
N x Fe	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Calculated on a dry weight basis and determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

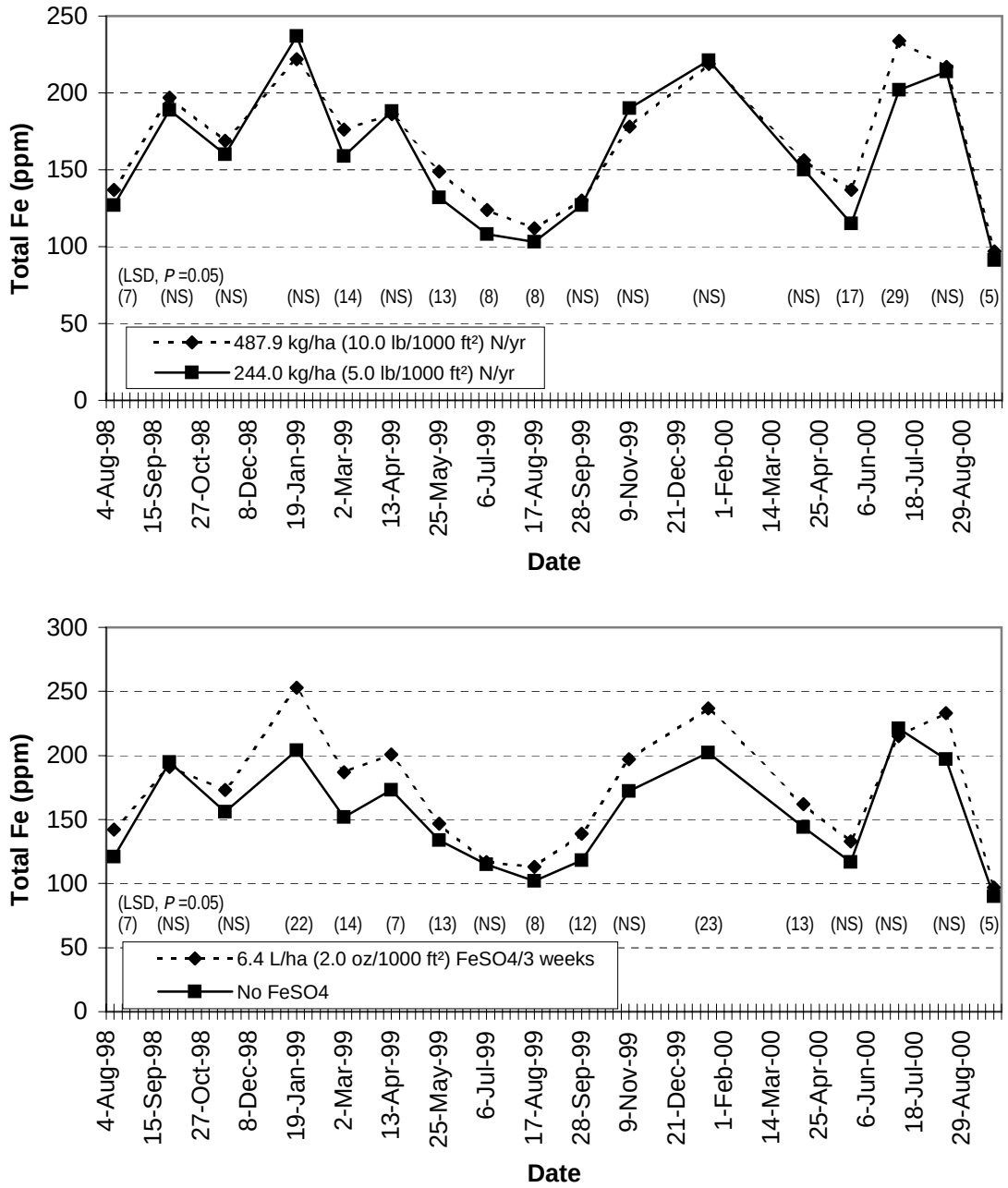
[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Figure 13. The effect of N and Fe treatments on total iron content of clippings of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.



Note: Mean comparisons conducted by a Fishers protected LSD test.

Note: K treatments basically did not affect total Fe content of clippings. Since clippings were collected from main plots, the cultivation effect could not be tested.

Note: A published target range for total iron content of clippings of an annual bluegrass putting green could not be located. A target range of 100 to 300 ppm total Fe was cited for creeping bentgrass [Nuss, J. 1994. Golf course management 62(2):120–128].

Table 19. The effect of N, K_2O, and $FeSO_4$ treatments on clipping iron content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Fe (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	137[x]	197	169	222	176	186	149	124	112	130	178	219	156	137	234	217	97
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	127	189	160	237	159	188	132	108	103	127	190	221	150	115	202	214	91
LSD, P=0.05	7	NS	NS	NS	14	NS	13	8	8	NS	NS	NS	NS	17	29	NS	5
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	131	190	157	233	177	184	140	115	108	130	184	218	151	124	222	203	93
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	132	196	172	225	161	190	141	117	107	128	184	221	155	127	213	229	94
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	142	191	173	253	187	201	147	117	113	139	197	237	162	133	215	233	97
No $FeSO_4$	121	195	156	204	152	173	134	115	102	118	172	202	144	117	221	197	90
LSD, P=0.05	7	NS	NS	22	14	7	13	NS	8	12	NS	23	13	NS	NS	NS	5
Summary of ANOVA effects[v]																	
Nitrogen (N)	**	NS	NS	NS	*	NS	**	***	*	NS	NS	NS	NS	*	*	NS	*
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	***	NS	NS	***	***	***	*	NS	**	**	NS	**	**	NS	NS	NS	**
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
K x Fe	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table 20. The effect of N, K_2O, and $FeSO_4$ treatments on soil salinity and fertility as determined by samples taken 7 May 1999.

		Soluble[z]						Exchangeable[z]			
Treatments	EC_e ($dS \cdot m^{-1}$)	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	TKN (%)	P-Olsen (ppm)	X-K (ppm)	X-Ca (ppm)	X-Mg (ppm)	X-Na (ppm)
N-fertility rate treatments[y]											
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	1.73[x]	191.4	47.4	178.1	3.0	0.172	59.5	65.2	1479.6	189.5	149.5
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	1.68	172.3	42.9	171.3	3.0	0.165	39.5	104.3	1499.6	167.2	149.5
LSD, P=0.05	NS	18.5	4.7	NS	NS	NS	NS	NS	NS	15.2	NS
K_2O-fertility rate treatments[y]											
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	1.78	186.4	46.2	173.8	2.9	0.169	52.0	120.6	1452.9	171.2	145.7
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	1.63	177.3	44.1	175.6	3.1	0.168	47.0	48.9	1526.4	185.4	153.3
LSD, P=0.05	0.13	NS	NS	NS	NS	NS	NS	52.8	NS	NS	NS
$FeSO_4$ level treatments[w]											
With $FeSO_4$	1.68	179.3	44.7	169.2	3.0	0.173	45.2	81.5	1519.7	179.4	153.3
No $FeSO_4$	1.73	184.4	45.6	180.2	3.0	0.164	53.8	88.0	1459.6	177.3	145.7
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]											
Nitrogen (N)	NS	*	*	NS	NS	NS	NS	NS	NS	**	NS
Potassium (K)	*	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]See Table A-9 for methodology details. Samples were from main (fertility) plots and included 14, 2-cm cores, from the 1.3- to 8.9-cm (0.5- to 3.5-inch) root zone.

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table 21. The effect of N, K_2O, and $FeSO_4$ treatments on soil salinity and fertility as determined by samples taken 10 Sept. 1999.

		Soluble[z]						Exchangeable[z]			
Treatments	EC_e ($dS \cdot m^{-1}$)	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	TKN (%)	P-Olsen (ppm)	X-K (ppm)	X-Ca (ppm)	X-Mg (ppm)	X-Na (ppm)
N-fertility rate treatments[y]											
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	1.39[x]	137.6	36.6	173.6	3.3	0.125	37.0	74.9	1427.8	151.0	143.7
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	1.44	141.1	38.0	175.8	3.2	0.137	39.6	84.7	1513.0	172.3	155.2
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	18.3	NS
K_2O-fertility rate treatments[y]											
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	1.39	137.8	37.2	172.5	3.2	0.132	37.1	81.5	1421.2	159.1	143.7
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	1.43	141.0	37.4	176.9	3.3	0.130	39.5	78.2	1519.7	164.2	155.2
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]											
With $FeSO_4$	1.42	140.1	37.4	174.0	3.2	0.131	39.0	81.5	1519.7	170.2	153.3
No $FeSO_4$	1.41	138.6	37.2	175.4	3.3	0.130	37.6	78.2	1421.1	153.0	145.7
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]											
Nitrogen (N)	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]See Table A-9 for methodology details. Samples were from main (fertility) plots and included 14, 2-cm cores, from the 1.3- to 8.9-cm (0.5- to 3.5-inch) root zone.

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table 22. The effect of N, K_2O, and $FeSO_4$ treatments on soil salinity and fertility as determined by samples taken 5 May 2000.

Treatments	EC_e ($dS \cdot m^{-1}$)	Soluble[z] Ca (ppm)	Soluble[z] Mg (ppm)	Soluble[z] Na (ppm)	SAR	TKN (%)	P-Olsen (ppm)	Exchangeable[z] X-K (ppm)	Exchangeable[z] X-Ca (ppm)	Exchangeable[z] X-Mg (ppm)	Exchangeable[z] X-Na (ppm)	pH	CEC (meq/100 g)
N-fertility rate treatments[y]													
487.9 $kg \cdot ha^{-1}$ (10.0 lb/1000 ft^2) N/yr	1.58[x]	178.3	36.7	160.0	3.0	0.179	81.9	74.9	1766.9	199.6	153.3	6.5	21.3
244.0 $kg \cdot ha^{-1}$ (5.0 lb/1000 ft^2) N/yr	1.53	163.7	34.2	164.3	3.0	0.178	83.8	88.0	1733.5	202.7	161.0	6.5	20.7
LSD, $P=0.05$	NS	13.3	NS	NS	.	NS	NS	12.7	NS	NS	NS	NS	NS
K_2O-fertility rate treatments[y]													
585.5 $kg \cdot ha^{-1}$ (12.0 lb/1000 ft^2) K_2O/yr	1.56	166.8	34.4	162.5	3.0	0.181	79.2	114.0	1728.4	199.6	159.1	6.5	21.3
195.2 $kg \cdot ha^{-1}$ (4.0 lb/1000 ft^2) K_2O/yr	1.54	175.2	36.5	161.8	3.0	0.176	86.5	48.9	1771.9	202.7	155.2	6.5	20.7
LSD, $P=0.05$	NS	NS	NS	NS	.	NS	NS	12.7	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]													
With $FeSO_4$	1.56	173.2	36.0	163.3	3.0	0.173	80.0	81.5	1736.8	201.7	153.3	6.5	22.0
No $FeSO_4$	1.55	168.8	35.0	161.0	3.0	0.184	85.8	81.5	1763.5	200.6	161.0	6.5	20.0
LSD, $P=0.05$	NS	NS	NS	NS	.	NS	NS	NS	NS	NS	NS	NS	1.5
Summary of ANOVA effects[v]													
Nitrogen (N)	NS	*	NS	NS	.	NS	NS	*	NS	NS	NS	NS	NS
Potassium (K)	NS	NS	NS	NS	.	NS	NS	***	NS	NS	NS	NS	NS
N x K	NS	*	*	NS	.	NS	NS	NS	NS	*	*	NS	NS
Iron (Fe)	NS	NS	NS	NS	.	NS	NS	NS	NS	NS	NS	NS	**
N x Fe	NS	NS	NS	NS	.	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	.	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	.	NS	NS	NS	NS	NS	NS	NS	NS

[z]See Table A-9 for methodology details. Samples were from main (fertility) plots and included 14, 2-cm cores, from the 1.3- to 8.9-cm (0.5- to 3.5-inch) root zone.

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 $L \cdot ha^{-1}$ (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 $kg \cdot ha^{-1}$ (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 $kg \cdot ha^{-1}$ $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 $L \cdot ha^{-1}$ (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

Table 23. The effect of N, K_2O, and $FeSO_4$ treatments on soil salinity and fertility as determined by samples taken 8 Sept. 2000.

		Soluble[z]						Exchangeable[z]					
Treatments	EC_e ($dS \cdot m^{-1}$)	Ca (ppm)	Mg (ppm)	Na (ppm)	SAR	TKN (%)	P-Olsen (ppm)	X-K (ppm)	X-Ca (ppm)	X-Mg (ppm)	X-Na (ppm)	pH	CEC (meq/100 g)
N-fertility rate treatments[y]													
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	1.65[x]	140.1	47.1	237.5	4.3	0.118	59.6	92.7	1574.8	243.2	230.2	6.9	23.3
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	1.73	142.5	49.1	251.1	4.5	0.120	66.8	105.8	1581.5	251.3	244.7	6.9	23.0
LSD, P=0.05	NS	NS	NS	NS	NS	NS	5.1	NS	NS	NS	NS	NS	NS
K_2O-fertility rate treatments[y]													
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	1.68	140.0	47.8	239.8	4.3	0.120	61.1	109.7	1558.1	247.3	236.5	6.9	23.6
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	1.70	142.6	48.4	248.8	4.5	0.119	65.3	88.8	1598.2	247.2	238.5	6.9	22.8
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	13.7	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]													
With $FeSO_4$	1.75	144.0	49.0	253.6	4.6	0.115	61.8	101.5	1566.5	246.2	247.6	6.9	22.1
No $FeSO_4$	1.62	138.6	47.2	235.0	4.2	0.124	64.6	97.0	1589.8	248.3	227.4	6.9	24.3
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]													
Nitrogen (N)	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]See Table A-9 for methodology details. Samples were from main (fertility) plots and included 20, 2-cm cores, from the 1.3- to 8.9-cm (0.5- to 3.5-inch) root zone.

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

APPENDIX

Table A-1. Analyses of irrigation water samples taken in 1999 and 2000 (see Table A-9 for analyses methodology details).

Analysis	23 Mar. 1999	30 July 1999	21 Dec. 1999	22 Mar. 2000	25 July 2000	$\bar{X}$	SE
B (ppm)	0.4	0.4	0.4	0.4	0.3	0.4	0.02
Ca (ppm)	54.1	58.1	48.1	54.1	64.1	55.7	2.6
Cl (ppm)	106.4	127.7	113.5	113.5	127.7	117.8	4.3
CO_3 (ppm)	<3	<3	<3	<3	<3	<3	0
Cu (ppm)	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	0
EC ($dS \cdot m^{-1}$)	1.01	1.01	0.94	0.98	1.09	1.01	0.02
ESP (%)	4	3	3	3	3	3	0.2
Fe (ppm)	0.04	0.04	<0.02	<0.02	<0.02	<0.03	0.005
HCO_3 (ppm)	213.5	256.2	207.4	225.7	237.9	228.1	8.8
K-Sol (ppm)	16.3	15.8	14.8	15.0	16.3	15.6	0.3
Mg (ppm)	17.0	18.2	20.7	19.5	18.2	18.7	0.6
Mn (ppm)	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	0.002
Na (ppm)	119.6	112.7	115.0	110.4	119.6	115.5	1.8
NH_4-N (ppm)	1.95	7.37	1.22	2.17	<0.05	<2.55	1.26
NO_3-N (ppm)	1.36	1.21	4.04	0.47	5.67	2.55	0.99
P (ppm)	0.53	1.17	0.62	0.80	0.65	0.75	0.11
pH	7.4	7.0	7.4	7.3	7.0	7.2	0.1
SAR	4	3	3	3	3	3	0.2
Se (ppb)	0.4	0.6	13.8	11.5	0.1	5.3	3.0
SO_4-S (ppm)	38.8	41.2	35.4	33.0	46.4	39.0	2.3
Zn (ppm)	0.03	0.06	0.05	0.03	0.03	0.04	0.01

Table A-2. Estimation of nitrogen applied to the research plot through the irrigation water over a 12-month period.

Month	Irrigation water applied (inches)[z]	Concentration of total N (mg/L)[y]	lb N/1000 ft^2 applied through irrigation water
May 2000	5.10	7.18	0.19
June 2000	5.74	7.39	0.22
July 2000	5.90	6.80	0.21
Aug. 2000	6.23	4.03	0.13
Sept. 2000	3.79	3.38	0.07
Oct. 2000	2.04	3.19[x]	0.03
Nov. 2000	0.77	3.19[x]	0.01
Dec. 2000	0.88	3.19[x]	0.01
Jan. 2001	0.96	3.00	0.01
Feb. 2001	0.41	4.66	0.01
Mar. 2001	1.78	4.06	0.04
Apr. 2001	1.05	4.88	0.03
12-month total	34.65	–	0.96

[z] Based on cumulative monthly irrigation run-times and precipitation rate of the research site irrigation system as determined by catch-can tests.

[y] Water samples collected from the irrigation head at the research site in the last week of each month. Samples were transported to the County Sanitation Districts of Los Angeles County Water Reclamation Department shortly after collection where they were subsequently analyzed for ammonia nitrogen, organic nitrogen, nitrate nitrogen, and nitrite nitrogen content.

[x] Estimated values based on average concentration of Sept. 2000 and Jan. 2001 samples.

Table A-3. Monthly average concentrations of N at Industry Hills Golf Courses from May 2000 to Aug. 2001.

	23 May 2000	21 June 2000	25 July 2000	25 Aug. 2000	26 Sept. 2000	29 Jan. 2001	26 Feb. 2001	26 Mar. 2001	30 Apr. 2001	29 May 2001	25 June 2001	1 Aug. 2001	30 Aug. 2001
Ammonia N	3.2	3.4	3.5	1.6	2.0	1.6	<3.0	0.4	1.8	0.6	0.3	0.7	3.7
Organic N	3.1	1.9	1.6	1.2	1.0	1.2	1.6	2.0	1.5	2.2	2.4	0.3	1.5
Nitrate N	0.55	1.34	1.40	1.07	<0.30	0.19	<0.05	1.52	1.37	3.52	3.07	1.50	0.60
Nitrite N	0.33	0.75	0.30	0.16	0.08	<0.01	<0.01	0.14	0.21	0.88	0.34	0.27	0.44
Total N	7.18	7.39	6.80	4.03	<3.38	<3.00	<4.66	4.06	4.88	7.20	6.11	2.77	6.24

Table A-4. Monthly average concentrations of N at the San Jose Creek Water Reclamation Plant, East (SJC-WRP) from May 2000 to Aug. 2001.

	May 2000	21 June 2000	10 July 2000	17 Aug. 2000	11 Sept. 2000	2 Oct. 2000	19 Dec. 2000	10 Jan. 2001	8 Feb. 2001	6 Mar. 2001	17 Apr. 2001	14 May 2001	11 June 2001	24 July 2001	6 Aug. 2001
Ammonia N	9.7	9.2	9.0	6.4	6.8	8.5	6.3	6.2	7.3	7.8	7.3	7.3	5.0	5.4	7.0
Organic N	2.6	1.7	1.9	1.5	1.2	1.6	1.4	1.3	1.5	1.1	1.7	1.8	1.6	1.7	1.5
Nitrate N	2.02	1.79	3.33	3.28	3.24	2.81	3.66	3.78	3.48	3.36	4.20	4.83	4.96	4.12	3.16
Nitrite N	0.84	1.02	0.96	0.53	0.30	0.50	0.71	0.51	0.60	0.72	0.60	0.57	0.49	0.39	0.46
Total N	15.16	13.71	15.19	11.71	11.54	13.41	12.07	11.79	12.88	12.98	13.80	14.50	12.05	11.61	12.12

Figure A-1. Concentrations of **total N** from Industry Hills Golf Courses from May 2000 to Aug. 2001 and San Jose Creek Water Reclamation Plant, East from Oct. 1997 to Aug. 2001.

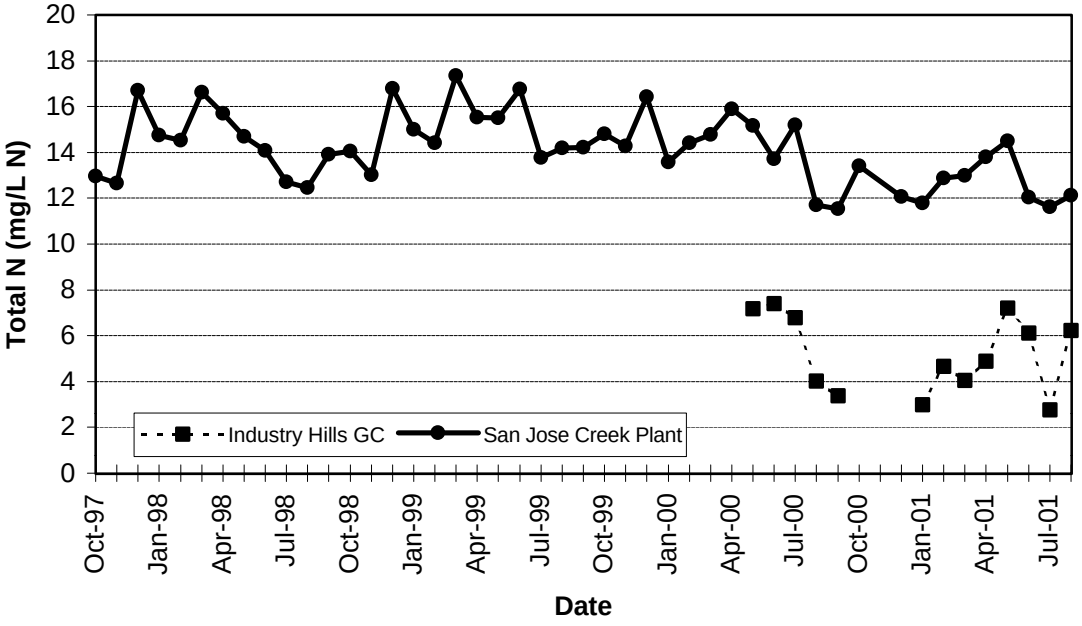


Table A-5. Annual average (January to December) concentrations of N at the San Jose Creek Water Reclamation Plant, East.

Year	Ammonia N	Organic N	Nitrate N	Nitrite N	Total N
	----------	----------	*mg·L*$^{-1}$	----------	----------
1975	7.0	1.6	4.4	0.25	13.25
1976	7.3	1.6	4.5	0.29	13.69
1977	11.9	2.1	2.1	0.67	16.77
1978	19.7	3.3	0.8	0.56	24.36
1979	16.6	2.0	1.0	0.59	20.19
1980	12.9	2.3	0.7	0.63	16.50
1981	14.4	1.8	0.4	0.45	17.06
1982	16.2	1.8	0.5	0.38	18.84
1983	14.1	2.0	1.4	0.93	18.47
1984	13.7	1.8	1.0	0.89	17.36
1985	11.4	1.7	2.5	1.03	16.63
1986	11.7	1.7	1.4	0.57	15.40
1987	12.3	1.6	0.7	0.60	15.12
1988	11.1	1.7	1.6	0.63	14.95
1989	11.6	2.0	0.7	0.66	14.95
1990	16.0	1.6	0.4	0.76	18.80
1991	12.7	1.7	2.9	0.96	18.25
1992	10.8	1.7	3.6	0.84	16.90
1993	9.0	1.2	2.3	1.76	14.32
1994	6.4	1.4	4.4	1.35	13.58
1995	7.6	1.7	3.4	1.48	14.21
1996	8.4	1.4	3.6	1.41	14.85
1997	9.8	1.4	1.92	1.24	14.36
1998	8.7	1.8	2.68	1.30	14.44
1999	9.9	1.8	2.38	1.11	15.18
2000	8.9	1.6	2.52	0.83	13.84

Table A-6. Overview of major activities for the annual bluegrass management study.

Date	Activity
1 June 1998 to 12 Oct. 1998	Application of HydroJect treatments for 1998 (applied every 4 weeks).
3 June 1998 to 11 Sept. 2000	Application of fertilizer treatments (applied every 3 weeks).
12 Aug. 1998 to 26 Sept. 2000	Clipping samples taken for NIRS and wet chemistry analyses (taken every 6 weeks) and Minolta spectrophotometer measurements (taken every 6 weeks through Jan. 2000 and every 3 weeks from Feb. to Sept. 2000).
12 Aug. 1998 to 26 Sept. 2000	Visual turfgrass quality ratings (taken every 6 weeks for a total of 15 rating dates), visual turfgrass color ratings (taken every 6 weeks through Jan. 2000 and every 3 weeks from Feb. to Sept. 2000 for a total of 23 rating dates). Note: ratings for seedhead coverage (16 rating dates), percent mottling/patchiness (11 rating dates), percent wilting and rolling (four rating dates), percent cool-season brown patch coverage (two rating dates), percent scalping (three rating dates), and percent phytotoxicity (one rating date) were taken on an as-needed basis during this period.
22 Oct. 1998	Core cultivation and topdressing.
21 Dec. 1998	Clipping yield [mowing height at 3.96 mm (0.156 inch)].
23 Mar. 1999	Clipping yield [mowing height at 3.96 mm (0.156 inch)].
31 Mar. 1999	Irrigation water sample taken (analysis by DANR).
7 May 1999	Soil core samples taken for elemental and morphological analyses.
28 May 1999 to 5 Oct. 1999	Application of HydroJect treatments for 1999 (applied every 3 weeks).
30 July 1999	Clipping yield [mowing height at 3.96 mm (0.156 inch)]; irrigation water sample taken (analysis by DANR).
10 Sept. 1999	Soil cores taken for elemental and morphological analyses.
22 Oct. 1999	Core cultivation [with 1.59 cm (0.625 inch) tines] and topdressing.
21 Dec. 1999	Clipping yield [mowing height at 3.30 mm (0.130 inch)]; irrigation water sample taken (analysis by DANR).
22 Mar. 2000	Clipping yield [mowing height at 3.81 mm (0.150 inch)]; irrigation water sample taken (analysis by DANR).
5 Apr. 2000 to 18 Sept. 2000	Application of HydroJect treatments for 2000 (applied every 3 weeks).
5 May 2000	Soil core samples taken for elemental and morphological analyses.
23 May 2000	Irrigation water samples collected (analysis by L.A. County).
21 June 2000	Irrigation water samples collected (analysis by L.A. County).
25 July 2000	Clipping yield [mowing height at 3.81 mm (0.150 inch)]; irrigation water samples collected (analyses by DANR and L.A. County).
25 Aug. 2000	Irrigation water samples collected (analysis by L.A. County).
8 Sept. 2000	Soil core samples taken for elemental and morphological analyses.
26 Sept. 2000	Irrigation water samples collected (analysis by L.A. County).

Table A-7. Calendar of activities for the annual bluegrass management study.

Date	Activity
1 June 1998	Mowing height at 3.96 mm (0.156 inch). Initial application of HydroJect treatments.
3 June 1998	Pre-trial soil fertilizer test. Initial application of fertilizer treatments.
16 June 1998	Plots verticut. Pesticide application (Chipco) to control dollar spot.
19 June 1998	Fertilizer treatments applied. Mowing height at 4.75 mm (0.187 inch).
23 June 1998	HydroJect treatments applied.
28 June 1998	Leaching event.
29 June 1998	Plots verticut.
14 July 1998	Fertilizer treatments applied.
21 July 1998	HydroJect treatments applied.
23 July 1998	Pesticide application (Dursban) to control cutworms.
27 July 1998	Plots verticut. Leaching event.
5 Aug. 1998	Fertilizer treatments applied.
10 Aug. 1998	Pesticide application (Daconil) to control dollar spot.
12 Aug. 1998	Initial clipping samples taken for NIRS and wet chemistry analyses. Initial Minolta spectrophotometer measurements. Initial visual turfgrass ratings (quality and color).
20 Aug. 1998	HydroJect treatments applied.
26 Aug. 1998	Fertilizer treatments applied.
3 Sept. 1998	Pesticides applied (Heritage and Daconil) to control summer patch and prevent anthracnose
8 Sept. 1998	Plots verticut.
16 Sept. 1998	Fertilizer treatments applied.
28 Sept. 1998	Leaching event. Mowing height at 3.58 mm (0.141 inch).
29 Sept. 1998	HydroJect treatments applied.
30 Sept. 1998	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements.
6 Oct. 1998	Fertilizer treatments applied.
12 Oct. 1998	HydroJect treatments applied.
19 Oct. 1998	Mowing height at 3.96 mm (0.156 inch).
20 Oct. 1998	Plots lightly topdressed.
22 Oct. 1998	Core cultivation [with 1.59 cm (0.625 inch) tines] and topdressing.
28 Oct. 1998	Fertilizer treatments application.
29 Oct. 1998	Pesticide application (Eagle) to control dollar spot.
9 Nov. 1998	Pesticide application (Eagle) to control dollar spot.
10 Nov. 1998	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (color).
18 Nov. 1998	Fertilizer treatments applied. Pesticide application (Terraclor) to prevent snow mold.
19 Nov. 1998	Plots verticut and lightly topdressed
8 Dec. 1998	Fertilizer treatments applied.
11 Dec. 1998	Plots verticut (with groomers) and lightly topdressed.
21 Dec. 1998	Initial clipping yield [mowing height at 3.96 mm (0.156 inch)].
22 Dec. 1998	Visual turfgrass ratings (quality and color).
6 Jan. 1999	Fertilizer treatments applied.
8 Jan. 1999	Plots lightly topdressed.
19 Jan. 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality and color).
29 Jan. 1999	Fertilizer treatments applied.
2 Feb. 1999	Plots verticut and lightly topdressed.
12 Feb. 1999	Pesticide application (Terraclor) to control snow mold.
17 Feb. 1999	Fertilizer treatments applied.
25 Feb. 1999	Leaching event.

Table A-7 *(continued)*. Calendar of activities for the annual bluegrass management study.

Date	Activity
2 Mar. 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, and seedhead coverage). Plots verticut.
10 Mar. 1999	Fertilizer treatments applied.
23 Mar. 1999	Clipping yield [mowing height at 3.96 mm (0.156 inch)].
25 Mar. 1999	Pesticide application (Terraclor) to control snow mold.
29 Mar. 1999	Plots verticut (two passes).
30 Mar. 1999	Plots lightly topdressed.
31 Mar. 1999	Fertilizer treatments applied. Irrigation water sample taken for analysis by DANR. Visual turfgrass ratings (seedhead coverage).
Apr. to June 1999	Grooming once per week.
1 Apr. 1999	Pesticide application (Betasan) for crabgrass pre-emergence.
8 Apr. 1999	Pesticide application (Terraclor) to control snow mold.
9 Apr. 1999	Plots verticut.
13 Apr. 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (color and seedhead coverage).
21 Apr. 1999	Fertilizer treatments applied.
4 May 1999	Plots verticut.
6 May 1999	Mowing height at 3.76 mm (0.148 inch).
7 May 1999	Soil core samples taken for elemental and morphological analyses.
10 May 1999	Plots verticut.
11 May 1999	Plots lightly topdressed.
14 May 1999	Fertilizer treatments applied.
21 May 1999	Pesticide applications (Prostar and Banner) to control cool-season brown patch.
28 May 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, seedhead coverage, and percent cool-season brown patch coverage). HydroJect treatments applied.
1 June 1999	Plots verticut.
2 June 1999	Fertilizer treatments applied.
3 June 1999	Mowing height at 3.56 mm (0.140 inch).
9 June 1999	HydroJect treatments applied.
11 June 1999	Pesticide application (Banner) to prevent summer patch.
22 June 1999	Plots verticut.
23 June 1999	Fertilizer treatments applied.
26 June 1999	Leaching event.
29 June 1999	Mowing height at 3.30 mm (0.130 inch).
1 July 1999	HydroJect treatments applied.
2 July 1999	Pesticide application (Daconil) to control dollar spot.
6 July 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, seedhead coverage, and percent mottling/patchiness).
13 July 1999	Plots lightly topdressed.
14 July 1999	Fertilizer treatments applied.
19 July 1999	HydroJect treatments applied.
20 July 1999	Mowing height at 3.96 mm (0.156 inch).
21 July 1999	Pesticide application (Dursban) to control cutworms.
28 July 1999	Pesticide application (Dursban) to control cutworms.
30 July 1999	Clipping yield [mowing height at 3.96 mm (0.156 inch)]. Irrigation water sample taken for analysis by DANR. Visual turfgrass ratings (percent mottling/patchiness and percent cool-season brown patch coverage).
4 Aug. 1999	Fertilizer treatments applied.
9 Aug. 1999	HydroJect treatments applied. Visual turfgrass ratings (percent mottling/patchiness and percent wilting and rolling).
17 Aug. 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, seedhead coverage, and percent mottling/patchiness).

Table A-7 *(continued)*. Calendar of activities for the annual bluegrass management study.

Date	Activity
18 Aug. 1999	Pesticide application (Heritage and Daconil) to prevent summer patch.
25 Aug. 1999	Fertilizer treatments applied.
31 Aug. 1999	HydroJect treatments applied. Plots verticut (two passes) and lightly topdressed.
1 Sept. 1999	Mowing height at 3.81 mm (0.150 inch).
10 Sept. 1999	Soil cores taken for elemental and morphological analyses.
17 Sept. 1999	Fertilizer treatments applied.
20 Sept. 1999	HydroJect treatments applied.
27 Sept. 1999	Leaching event.
28 Sept. 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, and seedhead coverage).
30 Sept. 1999	Pesticide application (Dursban) to control cutworms.
2 Oct. 1999	Mowing height at 3.30 mm (0.130 inch).
5 Oct. 1999	HydroJect treatments applied. Plots lightly topdressed.
6 Oct. 1999	Fertilizer treatments applied.
12 Oct. 1999	Visual turfgrass ratings (percent mottling/patchiness and percent wilting and rolling).
18 Oct. 1999	Mowing height at 3.96 mm (0.156 inch).
22 Oct. 1999	Core cultivation [with 1.59 cm (0.625 inch) tines] and topdressing.
27 Oct. 1999	Fertilizer treatments applied.
9 Nov. 1999	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (color and seedhead coverage).
10 Nov. 1999	Plots verticut (two passes) and lightly topdressed.
19 Nov. 1999	Fertilizer treatments applied.
22 Nov. 1999	Mowing height at 3.81 mm (0.150 inch). Leaching event.
30 Nov. 1999	Plots hand mowed and groomed in one direction.
1 Dec. 1999	Plots groomed in one direction.
6 Dec. 1999	Plots verticut and lightly topdressed.
8 Dec. 1999	Fertilizer treatments applied.
20 Dec. 1999	Mowing height at 3.30 mm (0.130 inch).
21 Dec. 1999	Clipping yield [mowing height at 3.30 mm (0.130 inch)]. Irrigation water sample taken for analysis by DANR. Fertilizer treatments applied.
27 Dec. 1999	Mowing height at 3.81 mm (0.150 inch).
4 Jan. 2000	Plots verticut and lightly topdressed.
5 Jan. 2000	Fertilizer treatments applied.
18 Jan. 2000	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, and percent mottling/patchiness).
24 Jan. 2000	Mowing height at 3.30 mm (0.130 inch).
26 Jan. 2000	Fertilizer treatments applied.
3 Feb. 2000	Plots verticut (two passes) and lightly topdressed.
9 Feb. 2000	Minolta spectrophotometer measurements. Visual turfgrass ratings (color).
14 Feb. 2000	Pesticide application (PCNB 75% WP) to control pink snow mold.
29 Feb. 2000	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, and seedhead coverage).
7 Mar. 2000	Plots verticut and lightly topdressed.
8 Mar. 2000	Fertilizer treatments applied.
20 Mar. 2000	Mowing height at 3.81 mm (0.150 inch).
22 Mar. 2000	Clipping yield [mowing height at 3.81 mm (0.150 inch)]. Minolta spectrophotometer measurements. Irrigation water sample taken for analysis by DANR. Visual turfgrass ratings (color and seedhead coverage).
29 Mar. 2000	Fertilizer treatments applied.
5 Apr. 2000	HydroJect treatments applied.

Table A-7 *(continued)*. Calendar of activities for the annual bluegrass management study.

Date	Activity
10 Apr. 2000	Plots verticut (two passes) and lightly topdressed.
11 Apr. 2000	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, and seedhead coverage).
17 Apr. 2000	Mowing height at 3.30 mm (0.130 inch).
17–18 Apr. 2000	Leaching event via rainfall [71 mm (2.8 inches)].
19 Apr. 2000	Fertilizer treatments applied.
24 Apr. 2000	HydroJect treatments applied.
26 Apr. 2000	Plots verticut and lightly topdressed.
2 May 2000	Pesticide application (Heritage and Curalan) to prevent dollar spot and summer patch.
3 May 2000	Minolta spectrophotometer measurements. Visual turfgrass ratings (color, seedhead coverage, and percent cool-season brown patch coverage).
5 May 2000	Soil core samples taken for elemental and morphological analyses.
8 May 2000	Plots verticut (two passes) and lightly topdressed.
10 May 2000	Fertilizer treatments applied.
15 May 2000	HydroJect treatments applied.
23 May 2000	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, seedhead coverage, and percent mottling/patchiness). Irrigation water samples collected for analysis by L.A. County.
31 May 2000	Fertilizer treatments applied. Leaching event.
5 June 2000	HydoJect treatments applied.
6 June 2000	Plots verticut (two passes) and lightly topdressed.
19 June 2000	Mowing height at 3.81 mm (0.150 inch).
21 June 2000	Fertilizer treatments applied. Irrigation water samples collected for analysis by L.A. County.
22 June 2000	Plots verticut and lightly topdressed. Pesticide application (Heritage and Fore) to prevent dollar spot and summer patch.
25 June 2000	Leaching event cancelled due to high temperatures.
26 June 2000	HydroJect treatments applied.
5 July 2000	Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, seedhead coverage, percent mottling/patchiness, and percent scalping).
6 July 2000	Plots verticut and lightly topdressed.
7 July 2000	Clipping samples taken for NIRS and wet chemistry analyses.
12 July 2000	Fertilizer treatments applied. Pesticide application (Heritage and Fore) to prevent dollar spot and summer patch.
17 July 2000	HydroJect treatments applied.
19 July 2000	Visual turfgrass ratings (percent mottling/patchiness and percent wilting and rolling).
25 July 2000	Clipping yield [mowing height at 3.81 mm (0.150 inch)]. Minolta spectrophotometer measurements. Irrigation water samples collected for analysis by DANR and L.A. County. Visual turfgrass ratings (color).
30 July 2000	Leaching event cancelled due to high temperatures.
2 Aug. 2000	Fertilizer treatments applied.
7 Aug. 2000	HydroJect treatments applied.
18 Aug. 2000	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, seedhead coverage, percent mottling/patchiness, and percent scalping). Mowing height at 4.762 mm (0.1875" inch).
22 Aug. 2000	Pesticide application (Heritage) to prevent dollar spot and summer patch. Pesticide application (Scimitar) to control cutworms.
23 Aug. 2000	Fertilizer treatments applied.
25 Aug. 2000	Irrigation water samples collected for analysis by L.A. County.
28 Aug. 2000	HydroJect treatments applied.
5 Sept. 2000	Minolta spectrophotometer measurements. Visual turfgrass ratings (color). Plots verticut (two passes) and lightly topdressed.
8 Sept. 2000	Soil core samples taken for elemental and morphological analyses.

Table A-7 *(continued)*. Calendar of activities for the annual bluegrass management study.

Date	Activity
11 Sept. 2000	Mowing height at 3.96 mm (0.156 inch). Fertilizer treatments applied.
18 Sept. 2000	HydroJect treatments applied.
19 Sept. 2000	Visual turfgrass ratings (seedhead coverage, mottling/patchiness, and percent wilting and rolling).
26 Sept. 2000	Clipping samples taken for NIRS and wet chemistry analyses. Minolta spectrophotometer measurements. Visual turfgrass ratings (quality, color, percent scalping, and percent phytotoxicity). Irrigation water samples collected for analysis by L.A. County.

Table A-8. Toro Research and Development Laboratory methods.

ANALYSES OF TOTAL N, C, and S

Quantitative determination of total nitrogen and total carbon in botanical materials using a resistance furnace and a thermal conductivity detector (combustion gas analyzer method).

Quantitative determination of total sulfur in botanical materials using an induction furnace and a thermal conductivity detector (combustion gas analyzer method).

Methodologies from Western States Program, Ver. 4.10 (2/10/98).

Literature:

Beaton, J.D., G.K. Burns and J. Platou. 1968. Determination of sulfur in soils and plant material. Technical Bulletin No. 14, The Sulfur Institute, Washington, D.C. 1968.

McGeehan, S.L. and D.V. Naylor. 1988. Automated instrumental analysis of carbon and nitrogen in plant and soil samples. Comm. in Soil Sci. Plant Anal. 19:493-505.

Sheldrick, B.H. 1986. Test of the LECO CHN-600 Determinator for soil carbon and nitrogen analysis. Can. J. Soil Sci. 66:543-545.

Shepers, J.S., D.D. Francis, and M.T. Thompson. 1989. Automated total nitrogen of soil and plant samples. Comm. in Soil Sci. Plant Anal. 20:949-959.

Sweeney, R.A. 1989. Generic combustion method for determination of crude protein in feeds: collaborative study. J. Assoc. Off. Anal. Chem. 72:770-774.

Yeomans, J.C. and J.M. Bremmer. 1991. Carbon and nitrogen analysis of soils by automated combustion techniques. Comm. in Soil Sci. Plant Anal. 22:843-850.

ANALYSES OF TOTAL P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, B, Mo, Al, and Ti

Quantitative determination of the concentration of P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, B, Mo, Al, and Ti in botanical materials using a high temperature dry oxidation of the organic matter and dissolution of the ash with hydrochloric acid. Digest analyte concentrations determined by inductively coupled Ar plasma atomic emission spectrometry (ICAP-AES).

Methodology from AOAC Official Method 985.01 (Metals and Other Elements in Plant and Pet Foods), AOAC Official Methods of Analysis (1995), Supplement Mar. 1996, 3.2.06. Also from Western States Program, Ver. 4.10 (2/10/98).

Literature:

Baker, D.E., G.W. Gorsline, C.G. Smith, W.L. Thomas, W.E. Grubs, and J.L. Ragland. 1964. Techniques for rapid analysis of corn leaves for eleven elements. Agron. J. 56:133-136.

Chapman, H.D. and P.F. Pratt. 1961. Methods of analysis for soils, plants, and waters. University of California, Berkeley, Division of Agricultural Sciences. Priced Publication 4034.

Isaac, R.A. and J.B. Jones Jr. 1972. Effects of various dry ashing temperatures on the determination of 13 elements in five plant tissues. Comm. Soil Sci. Plant Anal. 3:261-269.

Loshe, G. 1982. Microanalytical azomethine-H method for boron determination in plant tissue. Comm. Soil Sci. Plant Anal. 13:127-134.

Munter, R.C., T.L. Halverson and R.D. Anderson. 1984. Quality assurance of plant tissue analysis by ICP-AES. Comm. Soil Sci. Plant Anal. 15:1285-1322.

Soltanpour, P.N., G.W. Johnson, S.M. Workman, J.B. Jones and R.O. Miller. 1996. Inductively coupled plasma emission spectrometry and inductively coupled plasma-mass spectrometry, p. 91-139. *In:* J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. 3rd. ed. ASA and SSSA, Madison, WI. Book series no. 5.

Wear, J.I. 1985. Boron. p. 1059-1063. *In:* C.A. Black, et al (eds.) Methods of soil analysis, Part 2. Agron. Monogr. 9, ASA, Madison, WI.

Table A-9. DANR Analytical Laboratory soil, plant and water analyses methods.

Note: The soil and plant analyses information excerpted from the DANR Analytical Laboratory methodology and citation handout dated 3/5/97. The water analyses information was provided by DANR in May 1998 upon request.

SOIL SALINITY / ALKALINITY / TOXICITY ANALYSES

pH	Semi-quantifies soil pH using the saturated paste and pH meter. Determination: U.S. Salinity Laboratory Staff, 1954.
EC_e	Semi-quantifies the amount of soluble salts in the saturation paste extract using conductivity meter. Determination: Rhoades, 1982.
HCO_3, CO_3	Quantification of the bicarbonate (HCO_3) and carbonate (CO_3) in the saturated paste extract by titration with 0.05 Normal H_2SO_4 acid. Determination: Nelson, 1982.
Cl	Amount of chloride based on electrometric titration of the saturated paste extract by chloridometer. Determination: Rhoades, 1982.
B	ICP-AES determination of amount of boron in saturated paste extract. Extraction: Rhoades, 1982; determination: Soltanpour, et al, 1982.
Ca, Mg	Amounts of soluble calcium and magnesium in the saturated paste extract by inductively coupled plasmic atomic emission spectrometry. Extraction: Lanyon and Heald, 1982; determination, Soltanpour, et al, 1982.
Na, K(sol)	Amounts of soluble potassium and sodium in the saturated paste extract by emission spectrometry. Determination: Knudsen, Peterson and Pratt, 1982.
SAR	Sodium Absorption Ratio estimated calculation from calcium, magnesium and sodium on saturated paste extract. Calculation: U.S. Salinity Laboratory, 1954.
ESP	Estimated value for exchangeable sodium percentage. Calculated from SAR values. Calculation: U.S. Salinity Laboratory, 1954.

SOIL FERTILITY ANALYSES

X-K, X-Na, X-Ca, X-Mg	Equilibrium extraction of soil for plant available exchangeable potassium, sodium, calcium and magnesium using 1 Normal ammonium acetate (pH 7.0) and subsequent determination by atomic absorption/emission spectrometry. Extraction: Knudsen, Peterson and Pratt, 1982 and Lanyon and Heald, 1982. Measurement of exchangeable minerals residing on the soil colloid exchange sites is by displacement with buffered ammonium acetate solution. Determination: Franson, 1985.
Cu, Zn Mn, Fe	Equilibrium extraction of soil using DTPA and subsequent determination by atomic absorption spectrometry. Extraction: Lindsay and Norvell, 1978; determination: Franson, 1985.
Olsen-P	Extractable phosphate based on alkaline extraction by 0.5 Normal $NaHCO_3$. Plant available phosphate for soil with pH greater than 6.5 by ascorbic acid reduction of phosphomolybdate complex and measurement by spectrophotometry. Extraction and determination: Olsen, et al, 1954.
TKN	Total Kjeldahl Nitrogen in soil. Total reduced nitrogen by the wet oxidation of soil organic matter using standard Kjeldahl procedure with sulfuric acid and digestion catalyst. Extraction: Isaac and Johnson, 1976. Determination: Carlson, 1978.

SOIL PHYSIO-CHEMICAL ANALYSES

OM	Organic Matter by potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement (modified Walkley-Black). Determination: Nelson and Sommers, 1982.
CEC	Cation Exchange Capacity by barium acetate saturation and calcium replacement. Determination: Rible and Quick, 1960 and Janitzky, 1986.
PSA	Particle Size Analysis of sand, silt and clay in soil suspension by hydrometer. Determination: Gee and Bauder, 1979.

Table A-9 *(continued)*. DANR Analytical Laboratory soil, plant and water analyses methods.

PLANT TISSUE ANALYSES

N	Total Nitrogen by Nitrogen Gas Analyzer utilizing induction furnace and thermal conductivity (LECO FP-428). Sample size 100 mg, results corrected to 100% dry matter basis. Determination: Sweeney, 1989.
K	Total K, extraction by 2% acetic acid extraction. Quantitative determination by atomic emission spectrometry (AES). Extraction: Johnson and Ulrich, 1959; determination: Franson, 1985.
B, Ca, Mg, Mo, P, S	Totals, microwave acid digestion/dissolution of sample. Quantitative determination by atomic emission spectroscopy (ICP-AES). Digestion: Sah and Miller, 1992.
Na	Totals, microwave acid digestion/dissolution of sample. Quantitative determination by atomic emission spectrometry (AES). Digestion: Sah and Miller, 1992; determination, Franson, 1985.
Cu, Fe, Mn, Zn	Totals, microwave acid digestion/dissolution of sample. Quantitative determination by atomic emission spectrometry (AAS). Digestion: Sah and Miller, 1992; determination, Franson, 1985.

WATER SALINITY / ALKALINITY / TOXICITY ANALYSES

pH	Semi-quantifies H_2O pH using the pH meter. U.S. Salinity Laboratory, 1954.
EC	Semi-quantifies the amount of soluble salts in H_2O using the conductivity meter. Rhoades, 1982.
HCO_3, CO_3	Quantification of the bicarbonate (HCO_3) and carbonate (CO_3) in H_2O by titration with 0.05 Normal H_2SO_4 acid. Rhoades, 1982.
Cl	Amount of chloride based on electrometric titration of H_2O by chloridometer. Rhoades, 1982.
P	Quantitative determination by ascorbic acid reduction of phosphomolybdate complex and quantitative measurement by flow injection analysis. Franson, 1985.
SO_4-S	Amount of sulfate sulfur present in H_2O, by inductively coupled plasmic emission spectrometry. Soltanpour, et al, 1982.
B	ICP-AES determination of amount of boron in H_2O. Soltanpour, et al, 1982.
Ca, Mg	Amounts of soluble calcium and magnesium in H_2O by inductively coupled plasmic atomic emission spectrometry. Soltanpour, et al, 1982.
Na, K (sol)	Amounts of soluble potassium and sodium in H_2O by emission spectrometry. Knudsen, 1982.
SAR	Sodium Absorption Ratio estimated calculation from calcium, magnesium and sodium in H_2O. Calculation: U.S. Salinity Laboratory Staff, 1954.
ESP	Estimated value for exchangeable sodium percentage. Calculated from SAR values. Calculation: U.S. Salinity Laboratory Staff, 1954.
NO_3-N, NH_4-N	Determination by diffusion-conductivity analyzer. Carlson, 1978.
TKN	Total Kjeldahl Nitrogen in H_2O. Total reduced nitrogen by the wet oxidation of H_2O using standard Kjeldahl procedure with sulfuric acid and digestion catalyst. Carlson, 1978.
Zn, Cu, Mn, Fe	Determination by atomic absorption spectrometry. DeBoer and Reisenauer, 1973.
Se	Total selenium using nitric/perchloric acid digestion/dissolution of sample. Quantitative determination by vapor generation by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Determination: Tracy and Moeller, 1990.

References:

Carlson, R. M. 1978. Automated separation and conductimetric determination of ammonia and dissolved carbon dioxide. Anal. Chem. 50:1528-1531.

DeBoer, G. J. and H. M. Reisenauer, 1973. DTPA as an Extractant of Available Soil Iron. 121-128. Comm. In Soil Sci. Plant Anal. 4 (2).

Franson, M.A.H. (ed.) 1985. Method 303A. 157-160. In: Standard Methods for the Examination of Water and Wastewater. 16th Edition. APHA, AWWA, WPCF; Washington, D.C.

Gee, G.W. and J.W. Bauder. 1979. Particle size analysis by hydrometer: a simplified method for routine textural analysis and a sensitivity test of measurement parameters. Soil Sci. Soc. Am. J., Madison, WI 43:1004-1007.

Isaac, R.A. and W.C. Johnson. 1976. Determination of total nitrogen in plant tissue, using a block digestor. J. Assoc. Off. Anal. Chem. 59:98-100.

Janitzky, P. 1986. Cation exchange capacity. 21-23. In: Singer, M.J. and P. Janitzky (ed.) Field and Laboratory Procedures Used in a Soil Chromosequence Study. U.S. Geological Survey Bulletin 1648.

Johnson, C.M. and A. Ulrich. 1959. Analytical methods for use in plant analysis. Bulletin 766. Berkeley: University of California, Agricultural Experiment Station. 26-78.

Knudsen, D., G.A. Peterson and P.F. Pratt. 1982. Lithium, sodium, and potassium. 225-246. In: A. L. Page (ed.) Methods of Soil Analysis: Part 2: Chemical and Microbiological Properties. Monograph Number 9 (Second Edition). ASA, Madison, WI.

Lanyon, L.E. and W.R. Heald. 1982. Magnesium, calcium, strontium, and barium. 247-262. In: A. L. Page (ed.) Methods of Soil Analysis: Part 2: Chemical and Microbiological Properties. Monograph Number 9 (Second Edition). ASA, Madison, WI.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. Madison, WI. 42:421-428.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. 539-579. In: A. L. Page (ed.) Methods of Soil Analysis: Part 2: Chemical and Microbiological Properties. Monograph Number 9 (Second Edition). ASA, Madison, WI.

Nelson, R.E. 1982. Carbonate and gypsum. 181-197. In: A. L. Page (ed.) Methods of Soil Analysis: Part 2: Chemical and Microbiological Properties. Monograph Number 9 (Second Edition). ASA, Madison, WI.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dept. Agr. Cir. 939: 1-19.

Rhoades, J.D. 1982. Soluble salts. 167-179. In: A. L. Page (ed.) Methods of Soil Analysis: Part 2: Chemical and Microbiological Properties. Monograph Number 9 (Second Edition). ASA, Madison, WI.

Rible, J.M. and J. Quick. Apr., 1960. Water Soil Plant Tissue Tentative methods of analysis for diagnostic purposes. Method S-19:0. University of California Agricultural Experiment Service.

Sah, R.N. and R.O. Miller. 1992. Spontaneous reaction for acid dissolution of biological tissues in closed vessels. Anal. Chem. 64:230-233.

Soltanpour, P.N., J. Benton Jones, Jr., and S. M. Workman. 1982. Optical emission spectrometry. 29-65. In: A. L. Page (ed.) Methods of Soil Analysis: Part 2: Chemical and Microbiological Properties. Monograph Number 9 (Second Edition). ASA, Madison, WI.

Sweeney, R.A. 1989. Generic combustion method for determination of crude protein in feeds: collaborative study. J. Assoc. Off. Anal. Chem. 72:770-774.

Tracy, M. L. and G. Moeller. 1990. Continuous flow vapor generation for inductively coupled argon plasma spectrometric analysis. Part I. Selenium. J. Assoc. Off. Anal. Chem. 73:404-410.

U.S. Salinity Laboratory Staff. 1954. L.A. Richards (ed.) Diagnosis and Improvement of Saline and Alkali Soils. U.S. Department of Agriculture Handbook no. 60.

Table A-10. The effect of N, K_2O, and $FeSO_4$ treatments on clipping carbon content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total C (%)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	44.87[x]	43.63	44.41	47.47	48.66	48.31	47.61	48.18	48.84	48.97	48.46	47.61	47.07	49.46	47.92	47.50	48.83
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	44.84	43.16	43.97	46.12	46.84	47.48	47.10	47.08	48.34	49.35	48.21	46.58	45.68	48.51	47.46	45.67	49.11
LSD, P=0.05	NS	NS	NS	0.65	1.20	0.60	0.46	0.68	NS	NS	NS	NS	0.54	NS	NS	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	45.20	43.37	44.25	46.84	47.99	48.11	47.41	47.46	48.74	49.34	48.30	46.75	46.23	49.07	47.51	45.91	49.05
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	44.51	43.43	44.13	46.79	47.71	47.68	47.30	47.80	48.44	48.98	48.37	47.44	46.52	48.83	47.84	47.23	48.91
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	44.76	43.52	44.26	46.77	47.61	47.97	47.15	47.74	48.72	48.99	48.10	47.60	46.41	48.98	47.54	47.24	48.19
No $FeSO_4$	44.95	43.28	44.12	46.87	48.07	47.83	47.57	47.52	48.46	49.33	48.57	46.59	46.34	48.92	47.83	45.81	49.78
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	***	**	**	*	**	NS	NS	NS	NS	***	NS	NS	NS	NS
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Calculated on a dry weight basis and determined by combustion gas analyzer method (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-11. The effect of N, K_2O, and $FeSO_4$ treatments on clipping sulfur content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total S (%)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	0.46[x]	0.45	0.48	0.68	0.71	0.59	0.52	0.55	0.53	0.57	0.59	0.72	0.58	0.52	0.55	0.57	0.55
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	0.44	0.42	0.47	0.66	0.63	0.49	0.47	0.51	0.49	0.56	0.56	0.66	0.51	0.50	0.52	0.51	0.53
LSD, P=0.05	0.02	0.02	NS	NS	0.03	0.02	0.02	0.02	0.02	NS	0.01	0.03	0.02	0.02	0.01	0.05	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	0.45	0.43	0.48	0.68	0.71	0.55	0.49	0.53	0.51	0.57	0.58	0.69	0.54	0.50	0.53	0.52	0.54
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	0.45	0.44	0.47	0.66	0.65	0.53	0.50	0.53	0.51	0.55	0.57	0.69	0.55	0.51	0.54	0.55	0.54
LSD, P=0.05	NS	NS	NS	NS	0.03	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.01	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	0.45	0.43	0.48	0.67	0.68	0.54	0.49	0.53	0.51	0.55	0.57	0.69	0.55	0.51	0.53	0.54	0.52
No $FeSO_4$	0.45	0.44	0.47	0.67	0.68	0.54	0.50	0.53	0.51	0.57	0.59	0.69	0.54	0.51	0.54	0.53	0.56
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.01	NS	NS	NS	NS	NS	0.02
Summary of ANOVA effects[v]																	
Nitrogen (N)	*	*	NS	NS	***	***	***	***	***	NS	**	***	***	*	***	*	NS
Potassium (K)	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
N x K	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	**
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Calculated on a dry weight basis and determined by combustion gas analyzer method (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-12. The effect of N, K_2O, and $FeSO_4$ treatments on clipping calcium content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Ca (%)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	0.39[x]	0.39	0.38	0.40	0.42	0.39	0.40	0.40	0.35	0.34	0.43	0.38	0.38	0.36	0.40	0.39	0.26
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	0.38	0.39	0.38	0.40	0.39	0.33	0.36	0.36	0.35	0.34	0.43	0.37	0.35	0.34	0.39	0.39	0.26
LSD, P=0.05	NS	NS	NS	NS	0.02	0.02	0.02	0.01	NS	NS	NS	NS	0.02	0.01	0.01	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	0.39	0.39	0.37	0.38	0.38	0.32	0.35	0.38	0.35	0.33	0.41	0.35	0.35	0.34	0.39	0.38	0.26
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	0.38	0.39	0.39	0.42	0.44	0.40	0.41	0.39	0.35	0.35	0.45	0.39	0.37	0.36	0.40	0.40	0.27
LSD, P=0.05	NS	NS	0.01	0.03	0.02	0.02	0.02	NS	NS	NS	0.02	0.03	NS	0.01	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	0.37	0.39	0.38	0.40	0.40	0.36	0.38	0.37	0.35	0.34	0.43	0.37	0.37	0.35	0.39	0.39	0.26
No $FeSO_4$	0.40	0.39	0.38	0.41	0.41	0.36	0.38	0.39	0.35	0.34	0.43	0.38	0.36	0.36	0.40	0.39	0.27
LSD, P=0.05	0.02	NS	NS	NS	NS	NS	NS	0.01	NS	NS	NS	NS	NS	0.01	NS	NS	0.01
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	NS	**	***	***	***	NS	NS	NS	NS	*	***	**	NS	NS
Potassium (K)	NS	NS	**	**	***	***	***	NS	NS	NS	**	**	NS	***	NS	NS	NS
N x K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Iron (Fe)	*	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	**	NS	NS	*
N x Fe	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Calculated on a dry weight basis and determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-13. The effect of N, K_2O, and $FeSO_4$ treatments on clipping magnesium content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Mg (%)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	0.18[x]	0.17	0.19	0.20	0.22	0.18	0.18	0.20	0.27	0.17	0.22	0.23	0.17	0.19	0.191	0.22	0.22
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	0.18	0.17	0.17	0.17	0.19	0.16	0.17	0.18	0.18	0.17	0.21	0.19	0.16	0.18	0.186	0.22	0.21
LSD, P=0.05	NS	NS	0.01	0.01	0.02	0.01	0.01	0.01	NS	NS	NS	0.01	0.01	0.003	0.003	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	0.18	0.17	0.18	0.18	0.20	0.16	0.17	0.19	0.27	0.17	0.21	0.20	0.16	0.18	0.19	0.22	0.21
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	0.18	0.17	0.18	0.20	0.22	0.18	0.19	0.19	0.17	0.18	0.22	0.22	0.17	0.19	0.19	0.22	0.22
LSD, P=0.05	NS	NS	0.01	0.01	0.01	0.01	0.01	NS	NS	NS	NS	0.01	NS	0.003	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	0.18	0.17	0.18	0.19	0.21	0.17	0.18	0.18	0.27	0.17	0.21	0.20	0.17	0.18	0.18	0.21	0.21
No $FeSO_4$	0.18	0.17	0.18	0.19	0.21	0.17	0.18	0.20	0.18	0.17	0.22	0.21	0.17	0.19	0.19	0.22	0.22
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	0.01	NS	NS	NS	NS	NS	0.003	0.003	0.01	0.01
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	***	***	***	***	***	***	NS	NS	NS	***	**	***	**	NS	NS
Potassium (K)	NS	NS	**	***	***	***	***	NS	NS	NS	NS	*	NS	*	NS	NS	NS
N x K	NS	NS	NS	NS	NS	*	**	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	***	***	***	***
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
K x Fe	NS	NS	*	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS

[z]Calculated on a dry weight basis and determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-14. The effect of N, K_2O, and $FeSO_4$ treatments on clipping manganese content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Mn (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	39.73[x]	35.15	31.30	36.27	41.41	42.11	36.96	32.92	29.78	32.62	38.82	38.89	38.69	33.68	43.18	48.58	28.47
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	38.57	36.21	31.43	33.88	29.91	42.56	32.14	33.02	30.89	31.04	44.57	35.56	33.89	31.69	39.75	48.52	29.46
LSD, P=0.05	NS	NS	NS	NS	3.24	NS	1.63	NS	NS	1.27	4.49	NS	2.53	1.68	1.67	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	39.50	35.84	30.27	34.84	37.06	42.62	33.74	33.02	30.95	31.84	41.47	36.75	35.82	33.01	41.34	47.48	29.33
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	38.80	35.53	32.46	35.37	35.51	42.06	35.36	32.92	29.72	31.82	41.91	37.69	36.76	32.22	41.59	49.76	28.61
LSD, P=0.05	NS	NS	1.95	NS	NS	NS	1.63	NS	NS	NS	NS	NS	NS	NS	NS	1.78	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	37.48	34.54	30.67	34.22	35.62	41.17	33.67	30.85	28.97	30.51	39.47	33.92	35.64	31.92	39.59	45.27	25.87
No $FeSO_4$	40.82	36.83	32.06	36.06	36.85	43.51	35.44	35.09	31.69	33.16	43.91	40.53	36.95	33.40	43.33	51.82	32.12
LSD, P=0.05	1.90	1.50	NS	NS	NS	NS	1.63	1.69	1.76	1.27	4.49	3.44	NS	1.68	1.67	1.78	2.93
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	NS	***	NS	***	NS	NS	*	**	NS	***	**	***	NS	NS
Potassium (K)	NS	NS	*	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
N x K	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	***	**	NS	NS	NS	NS	*	***	**	***	*	***	NS	*	***	***	***
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	*	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-15. The effect of N, K_2O, and $FeSO_4$ treatments on clipping boron content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total B (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	20.91[x]	16.20	14.72	12.06	34.01	11.27	23.46	32.11	17.67	16.61	9.49	26.47	26.72	12.44	17.81	23.24	21.64
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	19.96	14.39	10.95	11.06	31.56	12.62	17.54	27.07	14.66	15.25	9.05	25.17	21.94	10.12	16.32	24.26	15.80
LSD, P=0.05	NS	NS	2.42	NS	NS	0.73	2.51	4.12	1.91	NS	NS	NS	4.67	0.86	NS	NS	4.13
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	19.02	14.45	11.91	11.67	33.98	12.01	19.47	29.42	15.80	15.55	9.09	27.62	23.53	11.13	16.58	22.87	17.56
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	21.84	16.15	13.75	11.49	31.91	11.88	21.54	29.76	16.52	16.31	9.45	24.02	25.13	11.27	17.55	24.83	19.63
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	20.49	15.86	12.68	11.73	36.03	12.16	22.07	31.23	17.14	16.74	9.80	26.95	26.60	11.67	17.62	25.76	19.32
No $FeSO_4$	20.38	14.73	12.98	11.41	30.00	11.73	18.93	27.95	15.18	15.12	8.74	24.69	22.06	10.66	16.51	21.80	17.73
LSD, P=0.05	NS	NS	NS	NS	3.49	NS	2.51	NS	1.91	NS	NS	NS	NS	NS	NS	3.19	NS
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	**	NS	NS	***	***	*	**	NS	NS	NS	*	***	NS	NS	**
Potassium (K)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	NS	*	NS	NS	NS	*	**	*	NS	NS	*	NS	NS	**	NS
Iron (Fe)	NS	NS	NS	NS	**	NS	*	NS	*	NS	NS	NS	NS	NS	NS	*	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-16. The effect of N, K_2O, and $FeSO_4$ treatments on clipping copper content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Cu (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	9.45[x]	10.42	12.37	12.73	13.34	12.64	9.87	9.75	7.65	10.40	12.21	15.43	8.94	9.39	7.61	8.69	7.86
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	9.58	10.82	12.53	11.30	13.94	12.52	10.29	11.41	8.76	11.32	13.16	15.16	9.40	10.83	8.63	10.67	10.26
LSD, P=0.05	NS	NS	NS	1.05	NS	NS	NS	0.95	0.54	NS	NS	NS	NS	0.91	NS	0.90	0.94
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	9.58	10.99	12.21	12.15	14.26	12.82	10.09	10.81	8.27	10.43	12.60	15.26	9.18	10.49	8.29	9.85	9.75
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	9.45	10.26	12.69	11.94	13.01	12.34	10.07	10.35	8.14	11.29	12.77	15.33	9.16	9.82	7.95	9.62	8.44
LSD, P=0.05	NS	NS	NS	NS	0.89	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.94
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	10.02	10.45	12.62	12.26	13.58	12.51	10.00	10.28	8.11	10.58	11.98	14.52	9.38	9.53	8.24	9.25	8.37
No $FeSO_4$	9.01	10.80	12.28	11.80	13.64	12.65	10.16	10.87	8.29	11.14	13.39	16.07	8.96	10.87	8.00	10.24	9.91
LSD, P=0.05	0.96	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.03	NS	NS	0.91	NS	0.90	0.94
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	**	NS	NS	NS	**	***	NS	NS	NS	NS	**	NS	***	***
Potassium (K)	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N x K	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
Iron (Fe)	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	**	NS	*	**
N x Fe	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
K x Fe	NS	NS	**	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-17. The effect of N, K_2O, and $FeSO_4$ treatments on clipping zinc content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Zn (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	71.21[x]	60.33	59.49	87.45	79.20	71.44	63.26	79.60	66.88	69.39	75.66	82.35	72.24	78.30	82.66	87.52	53.91
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	71.85	55.81	51.41	74.29	61.55	56.41	56.83	70.09	63.23	63.01	66.53	67.14	61.66	71.03	75.02	83.60	50.31
LSD, P=0.05	NS	3.40	4.20	6.27	3.35	3.10	2.54	2.74	NS	3.84	3.85	4.06	2.82	1.96	3.16	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	71.92	58.38	54.88	81.05	72.09	63.72	58.79	75.27	65.83	66.42	72.26	75.74	66.74	74.50	78.31	85.66	51.68
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	71.14	57.76	56.02	81.12	70.55	64.12	61.30	74.42	64.28	65.98	69.93	73.74	67.16	74.34	79.37	85.18	52.33
LSD, P=0.05	NS	NS	NS	NS	NS	NS	2.54	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	73.91	57.60	55.39	79.61	70.86	63.38	58.92	72.62	64.99	65.19	66.97	69.15	64.73	72.26	74.65	79.67	49.42
No $FeSO_4$	69.15	58.54	55.52	82.65	71.69	64.47	61.17	77.07	65.12	67.21	75.22	80.33	69.17	76.89	83.03	91.20	54.55
LSD, P=0.05	3.02	NS	NS	NS	NS	NS	NS	2.74	NS	NS	3.85	4.06	2.82	1.96	3.16	4.23	NS
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	*	***	***	***	***	***	***	NS	**	***	***	***	***	***	NS	NS
Potassium (K)	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	*	NS	*	NS	NS
Iron (Fe)	**	NS	NS	NS	NS	NS	NS	**	NS	NS	***	***	**	***	***	***	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	**	**	**	NS	NS
K x Fe	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-18. The effect of N, K_2O, and $FeSO_4$ treatments on clipping molybdenum content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Mo (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	7.49[x]	5.49	3.54	2.33	3.45	2.57	5.34	8.30	5.37	5.66	3.98	2.25	4.99	6.55	9.15	8.28	4.97
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	7.35	5.33	3.61	2.46	3.00	2.80	5.84	8.79	5.98	5.88	3.81	1.91	4.41	6.69	9.23	8.17	4.91
LSD, P=0.05	NS	NS	NS	NS	NS	NS	0.42	NS	0.33	NS	NS	0.32	0.40	NS	NS	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	7.47	5.40	3.53	2.20	3.14	2.62	5.53	8.45	5.62	5.52	3.78	1.99	4.59	6.48	9.09	8.22	4.90
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	7.37	5.42	3.62	2.57	3.35	2.75	5.66	8.64	5.73	6.02	4.01	2.18	4.80	6.78	9.28	8.22	4.99
LSD, P=0.05	NS	NS	NS	0.31	NS	NS	NS	NS	NS	0.42	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	7.03	5.27	3.49	2.21	3.07	2.73	5.36	8.48	5.51	5.54	3.59	1.75	4.58	6.23	8.49	7.70	4.59
No $FeSO_4$	7.81	5.54	3.66	2.59	3.41	2.64	5.82	8.61	5.85	6.00	4.20	2.41	4.82	7.08	9.88	8.74	5.29
LSD, P=0.05	0.46	0.25	NS	0.31	NS	NS	0.42	NS	0.33	0.42	0.42	0.32	NS	0.34	0.94	0.57	0.26
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	NS	NS	NS	*	NS	***	NS	NS	*	**	NS	NS	NS	NS
Potassium (K)	NS	NS	NS	*	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
N x K	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
Iron (Fe)	**	*	NS	**	NS	NS	*	NS	*	*	**	***	NS	***	**	***	***
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-19. The effect of N, K_2O, and $FeSO_4$ treatments on clipping sodium content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Na (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	1515[x]	1942	1733	1231	1178	553	1006	1342	1300	1377	1764	1467	718	995	1023	1148	1575
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	1617	2054	1860	1598	1361	674	1074	1292	1361	1398	1921	1768	868	1006	968	1144	1771
LSD, P=0.05	NS	NS	115	122	131	120	NS	NS	NS	NS	NS	185	125	NS	46	NS	127
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	1485	1960	1733	1357	1206	541	1000	1300	1316	1353	1794	1627	778	1008	990	1116	1625
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	1647	2035	1860	1458	1310	686	1080	1334	1345	1423	1899	1609	807	994	1001	1180	1741
LSD, P=0.05	NS	NS	115	NS	NS	120	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	1581	2018	1807	1417	1234	605	1026	1332	1318	1388	1834	1589	819	978	994	1170	1713
No $FeSO_4$	1551	1978	1785	1400	1285	622	1054	1302	1343	1387	1856	1646	766	1027	997	1122	1645
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	35	NS	NS	NS
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	*	***	**	*	NS	NS	NS	NS	NS	**	*	NS	*	NS	**
Potassium (K)	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	**	**	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
N x Fe	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-20. The effect of N, K_2O, and $FeSO_4$ treatments on clipping aluminum content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Al (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	30.98[x]	102.20	204.26	82.61	50.95	59.89	62.52	33.86	31.38	40.59	58.61	76.13	43.11	25.16	106.69	108.41	29.99
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	25.82	90.66	201.71	89.08	56.38	67.77	51.06	29.76	31.91	40.89	77.60	84.00	41.95	25.28	93.13	126.19	29.09
LSD, P=0.05	NS	NS	NS	NS	NS	6.35	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	26.28	92.33	191.96	87.17	57.51	60.99	57.85	30.40	30.96	43.77	70.50	77.20	42.23	24.82	103.27	105.24	30.25
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	30.53	100.52	214.01	84.41	49.53	66.68	55.74	33.22	32.33	37.71	65.71	82.94	42.83	25.63	96.55	132.35	28.67
LSD, P=0.05	NS	NS	21.68	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	26.93	91.97	210.55	84.16	57.49	64.16	56.26	29.77	32.49	41.21	69.99	75.51	43.91	24.59	98.81	140.15	30.49
No $FeSO_4$	29.88	100.88	195.43	87.43	49.56	63.51	57.33	33.85	30.80	40.27	66.22	84.63	41.14	25.95	101.02	95.64	28.53
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Potassium (K)	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Iron (Fe)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
K x Fe	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
N x K x Fe	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table A-21. The effect of N, K_2O, and $FeSO_4$ treatments on clipping titanium content of an annual bluegrass putting green from 12 Aug. 1998 to 26 Sept. 2000.

	Total Ti (ppm)[z]																
	Date																
Treatments	12 Aug. 1998	30 Sept. 1998	18 Nov. 1998	19 Jan. 1999	2 Mar. 1999	13 Apr. 1999	28 May 1999	6 July 1999	17 Aug. 1999	28 Sept. 1999	9 Nov. 1999	18 Jan. 2000	11 Apr. 2000	23 May 2000	7 July 2000	18 Aug. 2000	26 Sept. 2000
N-fertility rate treatments[y]																	
487.9 kg·ha^{-1} (10.0 lb/1000 ft^2) N/yr	1.39[x]	2.03	3.68	3.53	1.72	1.97	1.86	1.57	0.94	1.34	1.98	2.78	0.70	0.53	0.67	3.01	0.44
244.0 kg·ha^{-1} (5.0 lb/1000 ft^2) N/yr	1.47	2.00	3.53	3.14	1.78	2.35	1.71	1.40	0.97	1.54	2.61	2.83	0.69	0.55	0.60	3.05	0.43
LSD, P=0.05	NS	NS	NS	NS	NS	0.27	NS	NS	NS	NS	0.61	NS	NS	NS	NS	NS	NS
K_2O-fertility rate treatments[y]																	
585.5 kg·ha^{-1} (12.0 lb/1000 ft^2) K_2O/yr	1.25	1.91	3.46	3.60	2.01	2.18	1.77	1.55	0.91	1.54	2.42	2.77	0.71	0.53	0.63	2.67	0.46
195.2 kg·ha^{-1} (4.0 lb/1000 ft^2) K_2O/yr	1.61	2.12	3.75	3.11	1.50	2.15	1.80	1.43	0.99	1.34	2.16	2.84	0.68	0.55	0.63	3.44	0.41
LSD, P=0.05	NS	0.21	NS	NS	0.35	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
$FeSO_4$ level treatments[w]																	
With $FeSO_4$	1.45	1.99	3.77	3.28	1.90	2.22	2.02	1.34	0.98	1.49	2.38	2.63	0.72	0.55	0.64	3.67	0.47
No $FeSO_4$	1.41	2.04	3.44	3.41	1.60	2.10	1.55	1.64	0.93	1.39	2.20	2.98	0.67	0.53	0.62	2.40	0.40
LSD, P=0.05	NS	NS	NS	NS	NS	NS	0.36	NS	NS	NS	NS	NS	NS	NS	NS	0.96	NS
Summary of ANOVA effects[v]																	
Nitrogen (N)	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Potassium (K)	NS	*	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
Iron (Fe)	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
N x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x K x Fe	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS

[z]Determined by dry ashing, leachate, and inductively coupled Ar plasma (ICAP) emission spectrometry (see Table A-8 for details).

[y]N-P_2O_5-K_2O fertility treatments applied foliarly to each main plot every 3 weeks, utilizing a CO_2 sprayer mounted on a cart, and watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)]. N and K_2O applied at specified annual rates. P_2O_5 applied at 146.4 kg·ha^{-1} (3.0 lb P_2O_5/1000 ft^2) per year. See Table 2 for more details.

[x]Mean separation with Fisher's Protected LSD test.

[w]Fe applied foliarly to each main plot every 3 weeks, at 6.1 kg·ha^{-1} $FeSO_4$ (2.0 oz/1000 ft^2 $FeSO_4$) per application, utilizing a CO_2 sprayer mounted on a cart, immediately after N-P_2O_5-K_2O fertility treatments, and not watered in [finish spray volume 855.3 L·ha^{-1} (2.1 gal/1000 ft^2)].

[v]Randomized complete block design (RCB) with fertilizer treatments arranged in a 2x2x2 factorial arrangement.

[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.