Fall Performance and Post-dormancy Growth of 'Midiron' Bermudagrass in Response to Nitrogen, Iron, and Benzyladenine

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Abstract. Field research was conducted to determine the effects of N, Fe, and benzyladenine (BA) on fall performance, post-dormancy recovery, and storage nonstructural carbohydrate composition of 'Midiron' bermudagrass [*Cynodon dactylon* (L.) Pers.]. Fall green color retention and turf quality were superior for 48 than for 24 kg N/ha per month. Nitrogen level did not affect post-dormancy recovery or nonstructural carbohydrate levels in stolons and rhizomes measured in Sept. and Nov. 1983 and 1984. Iron level did not influence turf color and quality during summer months. Biweekly application of 0.6 kg Fe/ha produced better retention of greenness and turf quality during Fall 1983 and 1984 and superior turf color in Spring 1985 than the 0 kg Fe/ha treatment. Better green turf coverage was obtained with the biweekly than the monthly Fe (1.2 kg-ha⁻¹) treatment during Fall 1983. In contrast, monthly Fe produced color and turf quality similar to that of the biweekly Fe treatment during Fall 1984. Nonstructural carbohydrates were similar among Fe levels in 1983 and 1984. The effects of Fe on turf color and quality were similar at each level of N and BA. BA level did not consistently influence turf color or quality and did not affect storage carbohydrate levels. When used in conjunction with moderate summer N fertilization, foliar-applied Fe can extend bermudagrass quality during fall without adversely affecting postdormancy recovery. Chemical name used: *N*-(phenylmethyl)-1H-purin-6-amine (benzyladenine, BA).

Bermudagrass ceases growth and becomes discolored when exposed to chilling temperatures (3–5). Chilling stress occurs in grasses of tropical and subtropical origin at temperatures of 15 to 0°C (12). Chilling injury of bermudagrass is characterized by the presence of necrotic lesions, chlorophyll loss, and subsequent leaf discoloration, and cessation of growth (4, 10, 23). Disruption, of photosynthesis, respiration, and carbohydrate partitioning at chilling temperatures (21) contribute to reduced bermudagrass growth.

Pretreatment of 'Tifgreen' and 'Midiron' bermudagrass with 120 mg Fe/m² maintained a 23% higher average daytime CO₂ exchange rate (CER) than within 0 mg Fe/m² after 4 days at a 10/7°C chilling regime and following a 2-hr recovery period at 30°C after exposure to chilling (21). Nighttime CER before and after the chilling regime was not significantly affected by Fe. However, average nighttime CER was 28% higher for the 120 than the 0 mg Fe/m² treatment after recovery from chilling. Darker green turf color was observed for the 120 than for the 0 mg Fe/m² treatment after the chilling period, although no difference in chlorophyll content was detected among Fe treatments.

Iron deficiency in turf is often caused by factors that reduce the availability of Fe in soils and the ability of plants to take up and translocate sufficient amounts (19). Iron absorption and

translocation in centipedegrass [*Eremochloa ophiuroides* (Munro.) Hack.] was inhibited when night temperatures fell from 18 to 25°C down to –1 to 7°C (20).

Cytokinins affect translocation of some nutrient elements. Kinetin at 1.5 × 10⁻⁴ M stimulated mass flow transport of ³²P in phloem of corn (*Zea mays* L.) leaves to the kinetin application area (14). Translocation of ⁵⁹Fe from a primary bean (*Phaseolus vulgaris* L.) seedling leaf to a trifoliate leaf was increased by treatment of the trifoliate with kinetin (9). Chilling temperatures may inhibit cytokinin biosynthesis in chill-sensitive plant species (2).

The objective of this study was to evaluate the effect of late-summer and fall foliar applications of Fe and BA in conjunction with summer N fertilization on bermudagrass performance during fall and on post-dormancy recovery in spring. The effects of N, Fe, and BA on nonstructural carbohydrate accumulation in bermudagrass storage tissues were also studied.

Materials and Methods

The 2-year study was initiated in June 1983 and continued through 1985 on a six-year-old 'Midiron' bermudagrass turf growing in a Groseclose silt loam (clayey, kaolinitic, mesic Typic Hapludult) soil, pH 5.7, at the Turfgrass Research Center at Blacksburg, Va. A multiple split-plot experimental design with four replications was used. Whole plots were 4.5 × 3 m and consisted of monthly N fertilization treatments during June through September of 24 and 48 kg N/ha from NH₄NO₃.

Sub-plots were Fe treatments consisting of 0 or 1.2 kg-ha⁻¹ monthly, and 0.6 kg-ha⁻¹ biweekly from sodium ferric diethylene triamine pentaacetate during the period of 15 July through 15 Oct. Sub-sub-plots were 1.5 × 1.5 m and consisted of BA treatments of 0 and 0.062 kg-ha⁻¹ applied every 2 weeks (0.124 kg-ha⁻¹ month⁻¹) from 15 Aug. through 15 Oct. Nitrogen and

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Fe treatments were randomly arranged in rows and BA treatments were randomly arranged in column strips across N and Fe treatments within replications producing complete factorialization of treatments. A total of 48 plots was used. Fe and BA were applied using a compressed air boom sprayer that delivered 561 liters of aqueous solution/ha.

The plots were maintained at a 2.5-cm height by mowing one or two times per week with a reel mower with clippings being returned. Irrigation was applied as needed to maintain favorable growing conditions. Phosphorus (treble superphosphate) and K (KC1), were applied each June at 97 kg·ha⁻¹.

Visual ratings of bermudagrass color, taken at about weekly intervals, were based on 0 = no green turf cover and 100 = a complete, uniform cover. Turf quality ratings were used as an indication of treatment effects on bermudagrass performance during the fall. Turf quality was based on 1 = no live turf and 9 = dark green, dense, uniform turf. Bermudagrass color taken following dormancy break in spring and clipping yields taken in May 1984 and 1985 were used to assess treatment effects on post-dormancy recovery.

Two soil cores (10 cm in diameter × 10 cm deep) were collected at random from each plot on 30 Sept. and 24 Nov. 1983 and on 13 Sept. and 14 Nov. 1984. After washing soil from each core, samples were stored at -8C until rhizome and stolon tissue could be collected by hand separation. Rhizome and stolon tissue was dried for 1 hr at 100C, then for 24 hr at 65C in a forced-air oven. Tissue was then ground to pass a 40-mesh screen in a Cyclone Sample Mill (UD Corporation, Boulder, Colo.).

Rhizomes and stolons were analyzed for nonreducing and reducing sugars and starch (18) with modifications as outlined below. Water-soluble sugars were extracted by addition of 20 ml distilled H₂O to 100-ml test tubes containing 100-mg tissue samples and heating at 100C for 1 hr in a water bath. Following this initial extraction, a 4-ml aliquot of extract was removed and replaced by 4 ml of 0.8 N H₂SO₄. Samples were returned to a 100C water bath. After 1 hr, a 4-ml aliquot was again removed, and 8 ml of enzyme-buffer solution was added. The enzyme-buffer solution contained 4 ml of 15% takadiastase (Charase 40000, Miles Laboratories) and 4 ml of buffer [2 parts 0.2 N acetic acid : 3 parts 0.2 N sodium acetate, pH 4.9 (v/v)]. Samples were then incubated for 24 hr at 37C, after which a 4-ml aliquot was removed.

Reducing power of each 4-ml aliquot was immediately determined by automated colorimetric analysis following reaction with p-amino hydroxybenzoic acid hydrazide (11, 22). Nonreducing sugar content of tissue was taken as the difference in reducing power following incubation with dilute H₂SO₄ minus reducing power of the hot water extract. Starch content was taken as the difference in reducing power following enzyme digestion minus reducing power of the hot water extract. Carbohydrate content was expressed as glucose equivalents per kilogram of tissue.

All data were subjected to an analysis of variance. When a significant F ratio occurred for a treatment effect, a LSD was calculated.

Results and Discussion

Fall performance. The 48 kg N/ha treatment produced darker green, more-dense turf during June through early September than did plots fertilized with 24 kg N/ha (data not shown). Subsequently, fall bermudagrass color retention was superior for the 48 than the 24 kg N/ha treatment. Green turf coverage

was better for the former on 30 Sept. and 24 Oct. 1983 and from 4 Oct. through 7 Nov. 1984 (Table 1). Because first- and second-order interaction effects involving N, Fe, and BA were not significant ($P < 0.05$), only the main effects of treatments are presented.

'Tifgreen' bermudagrass fertilized with N during the fall remained a darker green longer, but was more susceptible to frost injury than turf that received only summer N (16). Although N was applied no later than the 2nd week in September in both years of this study, differences in turf color were evident among N application levels until 24 Oct. 1983 and 7 Nov. 1984. The superior color retention was associated with higher turf quality scores for the 48 than the 24 kg N/ha treatment until the 4th week of Oct. 1983 and the 2nd week of Oct. 1984 (Table 2).

No obvious visual differences in turf response to application levels of Fe occurred until September or October, when ambient air temperatures reached chilling or frost conditions (Fig. 1). A monthly application of 1.2 kg Fe/ha helped retain more green turf coverage than the 0 kg Fe/ha treatment by 13 Oct. and 4 Nov. 1983 and during 4 Oct. through 7 Nov. 1984 (Table 1). The monthly Fe treatment did not effectively improve bermudagrass turf quality scores in Fall 1983 compared to the 0 kg Fe/ha treatment (Table 2). However, turf quality during Sept. and Oct. 1984 was higher for monthly Fe applications than for 0 kg Fe/ha.

Greater green turf coverage was observed for the biweekly 0.6 kg Fe/ha treatment than for 0 kg Fe/ha during 30 Sept. through 4 Nov. 1983 and during 4 Oct. through 7 Nov. 1984 (Table 1). Better color retention by the biweekly Fe treatment compared to 0 kg Fe/ha resulted in superior turf quality scores for the former during Sept. and Oct. 1983 and 1984 (Table 2).

Green turf coverage was better with the biweekly than the monthly Fe treatment from 6 through 24 Oct. 1983 (Table 1). In contrast, the monthly Fe treatment produced green coverage similar to that of the biweekly Fe treatment during Fall 1984. The different response to timing of Fe application probably occurred because air temperatures declined more rapidly and earlier in Fall 1983 than in 1984 (Fig. 1).

BA tended to promote better color retention during Fall 1983 than in 1984 (Table 1). BA level did not influence fall turf quality in either year of this study (data not shown).

Post-dormancy growth. N application level the previous summer did not significantly affect post-dormancy recovery of 'Midiron' bermudagrass in 1984 or 1985 (data not shown). Increasing summer N fertilization rates decreased winter survival of coastal bermudagrass (1). However, bermudagrass recovery from winter damage was best with high-N fertilization in combination with high-K fertilization (8). Post-dormancy recovery of 'Midiron' was not affected by N application level, probably because the range of N rates used was narrow and considered moderate for bermudagrass turf. Also, 'Midiron' bermudagrass has good to excellent winter survival history in the mid-Atlantic United States (8).

BA treatment did not enhance post-dormancy recovery of 'Midiron' in Spring 1984 or 1985 (data not shown). However, a monthly application of 1.2 kg Fe/ha during the previous fall produced more green turf coverage than the 0 kg Fe/ha treatment during 21 May to 25 June 1984 and during 15 Apr. to 6 June 1985 (Table 3). Monthly Fe applications stimulated more rapid development of bermudagrass green coverage in Spring 1984 than the biweekly Fe treatment. However, no significant difference in green coverage occurred in Spring 1985 among the monthly and biweekly Fe treatments. The biweekly Fe treat-

Table 1. 'Midiron' bermudagrass color ratings during fall as influenced by summer N fertilization and Fe and BA application.^z

		Color ratings ^y											
		1983						1984					
		Sept.		Oct.		Nov.		Sept.		Oct.		Nov.	
Compound	Application level (kg·ha ⁻¹ ·month ⁻¹)	15	30	6	13	24	4	20	4	10	15	30	7
Nitrogen													
	24	74	60	63	64	61	38	94	87	72	61	58	29
	48	75	69	70	69	69	46	94	93	83	71	73	40
FLSD _{0.05} ^x		NS	5	NS	NS	7	NS	NS	4	7	9	13	8
Iron													
	0	69	62	62	61	60	30	93	87	65	51	56	22
	1.2	70	64	65	66	62	46	95	92	85	77	74	41
	0.6 + 0.6	75	68	73	74	71	49	95	92	83	70	68	42
FLSD _{0.05}		NS	4	5	4	3	5	NS	3	6	7	5	4
BA													
	0	71	62	65	65	63	39	95	90	75	63	64	35
	0.124	75	67	69	68	66	45	94	90	81	69	68	34
FLSD _{0.05}		NS	4	3	NS	NS	5	NS	NS	5	NS	NS	NS

^zNitrogen, Fe, and BA data are the means of 24, 16, and 24 observations, respectively.

^yColor ratings: 100 = complete green bermudagrass ground cover, 0 = no green turf cover.

^xFLSD, Fisher's LSD ($P \leq 0.05$) for comparison of treatment means within compounds.

^{ns}Not significant.

Table 2. Turf quality of 'Midiron' bermudagrass during fall as influenced by summer N fertilization and Fe application.^z

		Turf quality ^y							
		1983				1984			
		Sept.		Oct.		Sept.		Oct.	
Compound	Application level (kg·ha ⁻¹ ·month ⁻¹)	16	26	13	28	20	3	10	29
Nitrogen									
	24	5.5	5.5	4.2	3.0	5.6	5.4	4.7	4.6
	48	6.4	6.0	4.8	3.6	6.5	6.9	5.8	5.2
FLSD _{0.05} ^x		0.6	NS	0.5	0.4	0.5	0.7	0.4	NS
Iron									
	0	5.6	5.2	4.1	3.1	5.3	5.5	4.8	4.1
	1.2	5.6	5.6	4.3	3.0	6.3	6.5	5.6	5.2
	0.6 ± 0.6	6.7	6.2	4.8	3.5	6.6	6.5	5.3	4.9
FLSD _{0.05}		0.3	0.4	0.4	0.3	0.5	0.3	0.3	0.6

^zNitrogen, Fe, and BA data are the means of 24, 16, and 24 observations, respectively.

^yFLSD = Fisher's LSD ($P \leq 0.05$) for comparison of treatment means within compounds.

^xVisual quality: 9 = dark green, dense, uniform turf; 1 = no live turf.

^{ns}Not significant.

ments produced green turf coverage similar to the 0 kg Fe/ha treatment during Spring 1984, but the former was superior during Spring 1985.

Clipping yields were not significantly affected in May 1984 or 1985 by N, Fe, or BA levels. The significantly higher green turf coverage for the monthly compared to the biweekly Fe treatment without a corresponding increase in clipping yields appears contradictory. Iron applied in late September to common bermudagrass approaching the onset of dormancy had no effect on color ratings taken the following spring (13). 'Midiron' treated with Fe during summer and fall appeared to have darker green leaves in Spring 1984 and 1985 than 'Midiron' that received no Fe applications. This observation indicates that Fe applied the previous season may reduce chlorosis exhibited in bermudagrass turf in early spring under some environmental conditions. Because clipping yields did not differ significantly

among Fe application levels, the differences in 'Midiron' green coverage during spring may have occurred primarily due to chlorosis in the 0 kg Fe/ha treatment.

Nonstructural carbohydrates. Total nonstructural carbohydrates (TNC) and nonstructural carbohydrate components were similar among levels of N, Fe, and BA (data not shown). TNC in stolons changed relatively little from Sept. to Nov. 1983, but increased by 15% during a similar sampling interval in 1984 (Table 4). Stolon starch levels decreased by 20% from Sept. to Nov. in 1983 and decreased 32% during the same period in 1984. During this same period, reducing sugars increased 40% in 1983 and 144% in 1984, while nonreducing sugars increased 24% in 1983 and 275% in 1984.

Average rhizome TNC was similar during September and November for both years (Table 4). Similar to stolon starch levels, rhizome starch levels were 25% lower in 1983 and 29%

Fig. 1. Weekly average maximum and minimum temperature at Blacksburg, Va. during Aug. 1983 through May 1985.

Table 3. 'Midiron' bermudagrass color ratings and clipping yields during spring as influenced by Fe application.^z

Iron application level (kg·ha ⁻¹ ·month ⁻¹)	Color ratings ^y								Clipping dry wt. 1984-85 Mean g/plot
	1984					1985			
	May			June		April		June	
	7	14	21	10	25	15	30	6	
0	23	36	45	60	75	26	47	58	29
1.2	29	47	56	70	84	33	55	66	29
0.6 + 0.6	25	39	48	63	78	33	56	67	28
FLSD _{0.05}	NS	NS	6	5	4	5	8	7	NS

^zData are the means of 16 observations.

^yColor ratings: 100 = complete green bermudagrass ground cover, 0 = no green turf cover.

*FLSD = Fisher's LSD ($P \leq 0.05$) for comparison of treatment means within compounds.

^{NS}Not significant.

Table 4. Average total nonstructural carbohydrates (TNC) and nonstructural carbohydrate components in 'Midiron' bermudagrass stolons and rhizomes during fall.^z

Data of sampling	Stolons				Rhizomes			
	Sugars		Starch	TNC	Sugars		Starch	TNC
	Nonreducing	Reducing			Nonreducing	Reducing		
1983				(g·kg ⁻¹)				
30 Sept.	21	92	135	249	17	90	184	291
24 Nov.	26	129	92	247	21	128	131	280
FLSD _{0.05} ^y	3	13	16	NS	NS	15	21	NS
1984								
13 Sept.	8	45	231	283	7	47	311	366
14 Nov.	30	110	187	326	22	115	234	371
FLSD _{0.05}	4	7	27	26	4	14	23	NS

^zData are averages for 1983 and 1984.

^yFLSD = Fisher's LSD ($P \leq 0.05$) for comparison of means within years.

^{NS}Not significant.

lower in 1984 for the November than the September sampling. Rhizome reducing sugars increased 42% in 1983 and 145% in 1984, while nonreducing sugars increased by 24% in 1983 and 214% in 1984 from September to November. Similar increases in TNC in three other bermudagrass cultivars were reported previously (6). In 'U-3', 'Midway', and 'Westwood' bermudagrasses, starch levels gradually decreased, and reducing and nonreducing sugars increased slightly during late September to early December. Meyer zoysiagrass (*Zoysia japonica* Steud.) rhizomes and stolons accumulated TNC during September and

remained near 50% of dry weight until December (17). Reducing sugars remained low and unchanged, while total sugars gradually increased during fall.

Conversion of starch to sugar and accumulation of maximum sugar levels in perennials acclimated to low temperatures have been suggested to favor winter survival by plants (6, 7, 15). Accumulation of sugars in rhizome and stolon tissue may explain the relatively good winter survival exhibited by 'Midiron'. Because TNC levels were relatively high in stolons and rhizomes and TNC did not change dramatically during the sampling interval, TNC accumulation in 'Midiron' may not be as important to low temperature survival, as is the conversion of insoluble polysaccharides to water-soluble forms.

The results of this study indicate that, when used in conjunction with moderate summer N fertilization, foliar-applied Fe can improve the performance of bermudagrass during fall and hasten post-dormancy recovery in spring. The extension of bermudagrass performance during fall by Fe application does not adversely affect carbohydrate storage levels in bermudagrass rhizomes and stolons present at the onset of dormancy and does not appear to limit winter survival.

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