Late-season Applications of Various Nitrogen Sources Affect Color and Carbohydrate Content of 'Tiflawn' and Arizona Common Bermudagrass

J.M. Goatley, Jr.¹, V.L. Maddox², and K.L. Hensler³

Department of Plant and Soil Sciences, Mississippi State University, Mississippi State, MS 39762-9555

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Abstract. Bermudagrass turfs in the southern United States often receive late growing season applications of nitrogen (N) in order to sustain turfgrass color prior to dormancy, even though such applications might increase winterkill potential. Yearly research trials were initiated in the last week of Sept. 1989 to 1991 at Mississippi State Univ. to evaluate fall and spring color responses and rhizome levels of total nonstructural carbohydrates (TNC) of 'Tiflawn' and Arizona (AZ) Common bermudagrass [*Cynodon dactylon* L. (Pers.)] treated with various N sources delivering N at 98 kg·ha⁻¹ in a single application. The fertilizers were ammonium nitrate (AN), sulfur-coated urea (SCU), a natural organic ('Milorganite', NO), isobutylidene diurea (IBDU), ureaformaldehyde (UF), and methylene urea (MU). Color responses from N fertilization were most prominent in the fall except when there was an early frost event in Oct. 1990. The most rapid greening response and highest color ratings were consistently observed for the water-soluble AN. Of the slow-release sources, SCU, MU, and IBDU provided color responses as long as temperatures remained warm enough to promote bermudagrass growth. The NO source provided an unexpected, significant greening response in Oct. 1989 and 1991 on 'Tiflawn', but not on AZ Common. The UF consistently provided the lowest color ratings. There were virtually no differences in TNC levels between N treatments for either grass. At no time was there any indication that N fertilization increased bermudagrass winterkill potential; to the contrary, the predominant responses were better fall and spring color than the nontreated control.

Late growing season application of N to bermudagrass continues to be a controversial management practice performed by many turf managers in the southern United States in order to extend its growing period. Beard (1982) reported that late-season N applications increased vulnerability of bermudagrasses to winterkill and promoted winter diseases. Others reported that late-season N application prolonged desirable turfgrass color in the fall and again the following spring with no visible signs of increased winterkill (Goatley et al., 1994; Reeves et al., 1970; Schmidt et al., 1989). Late-season N applications could also affect the level of total nonstructural carbohydrates (TNC) in storage tissues. The TNC serve as the stored energy source for bermudagrass during winter dormancy and TNC levels reportedly increase as bermudagrass acclimates to colder weather (Dunn and Nelson,

1974; Thompson and Ward, 1965). However, late-season fertilization with water-soluble N had little effect on 'Tifgreen' bermudagrass rhizome TNC levels when sampled in December or March after fall N fertilization (Goatley et al., 1994).

Few data are available comparing the effects of various slow-release N (SRN) sources commonly used in bermudagrass fertility programs on late-season response. Some of the most common SRN sources used in turf management are sulfur-coated urea (SCU), natural organics (NO), isobutylidene diurea (IBDU), ureaformaldehyde (UF), and methylene urea (MU). For all of these SRN sources, smaller particle sizes, adequate moisture, and warmer temperatures generally increase N release rates, but for different reasons. The N release rates of SCU and IBDU are increased by having adequate soil moisture, warmer temperatures, and finer grade particle sizes (Allen et al., 1971; Lunt and Clark, 1969; Waddington et al., 1977; Waddington and Turner, 1980). Late fall and early spring color responses to IBDU treatment have been reported for cool season turfgrasses (Wilkinson, 1977; Woolhouse, 1983). The late- and early-season color response from IBDU was attributed to slow but continuous N mineralization which occurs in spite of cooler temperatures (Turner and Hummel, 1992).

In particular, cool temperatures limit N

release from NO and UF, and to some degree MU, because these fertilizers require microbial decomposition for such release (Hummel, 1980; Hummel and Waddington, 1981; Turner and Hummel, 1992; Yee and Love, 1946). However, NO applications to bermudagrass during the summer growing season in Louisiana stimulated both growth and yield more than did other N fertilizer sources (Barrios et al., 1982).

This research was conducted to evaluate the effects of late-season fertilization with one water-soluble and various SRN sources applied to 'Tiflawn' and Arizona (AZ) Common bermudagrasses on fall and spring color responses and total nonstructural carbohydrate levels in rhizomes.

Materials and Methods

The N sources used were commercially available formulations of water-soluble ammonium nitrate (34N-0P-0K) and slow-release N sources of SCU (36N-0P-0K), IBDU (36N-0P-0K), MU (36N-0P-0K), UF (36N-0P-0K), and a natural organic (6N-1P-0K; Milorganite, Milwaukee Metropolitan Sewerage District, Milwaukee). A nontreated control was also included for reference. All N sources were applied by hand at levels of 98 kg·ha⁻¹ to 1.8-m × 3.0-m plots of 'Tiflawn' and AZ Common bermudagrasses at the Mississippi State Univ. Plant Science Research Center, Mississippi State. Application dates were 29, 28, and 30 Sept. in 1989, 1990, and 1991, respectively. Treated turf areas were changed each year to ensure that there was no carryover from previous years' treatments. Soil type was a Marietta fine loam (fine-loamy, siliceous, thermic Fluvaquentic Eutrochrept) with a pH of 6.2 and P and K levels that ranged from 205-220 and 160-178 kg·ha⁻¹ across the 3 years when sampled prior to each trial's initiation. All turf areas received an application of 49, 22, and 41 kg·ha⁻¹ of N, P, and K, respectively, each June with 13N-6P-11K and an application of N at 49 kg·ha⁻¹ with 34N-0P-0K in mid-July. The turfs were mowed weekly at 5-cm cutting heights with clippings returned. Irrigation was supplied during the summer months only as needed to prevent moisture stress. Irrigation was applied at a level of 7.5 mm over a 30-min period following all fertilizer applications. Simazine [2-chloro-4,6-bis (ethylamino)-s-triazine] was applied at the level of 1.1 kg·ha⁻¹ in mid-October of each year for winter weed control.

Visual turfgrass color ratings were made periodically after N application using a scale of 1 to 9, where 1 = completely brown turf, 6 = minimal acceptable green color, and 9 = dark-green turf. Turf color ratings were made until the occurrence of killing frost in the fall and ratings resumed the following spring when color differences became obvious. Rhizome samples for TNC analysis were collected in mid-December of each year following N application. The collection methods and TNC determinations were as described previously (Goatley et al., 1994; Smith, 1981).

Experimental design in all yearly trials was

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¹Associate Professor/Agronomist.

²Research Assistant.

³Graduate Research Assistant.

a randomized complete block with three replications per treatment. Data were analyzed using the analysis of variance procedure of SAS (SAS Institute, 1987) and mean separation was performed using Fisher's protected least significant difference (LSD) test ($P \leq 0.05$). Data for individual yearly trial results are presented because of significant year $\times$ treatment interactions.

Results and Discussion

Color ratings. Ammonium nitrate and NO had induced a significant greening response on 'Tiflawn' bermudagrass at the first rating date, whereas all N sources except NO and UF increased color significantly for the AZ Common bermudagrass in 1989 (Table 1). The late growing season response of *Cynodon* sp. to water-soluble N sources has been previously reported (Goatley et al., 1994; Reeves et al., 1970; Schmidt et al., 1989), but the color response from the NO on 'Tiflawn' was not anticipated. About 8% of the total N in the NO was readily available, but at the application rate of 98 kg-ha⁻¹, this still supplied only ≈ 8 kg-ha⁻¹ of readily available N initially, an amount not expected to produce a significant color response on 'Tiflawn'. By 20 Oct. all N sources other than UF had increased green color relative to the control in AZ Common bermudagrass, and all sources other than SCU, UF, and IBDU had increased color in 'Tiflawn'. The first light frosts of the fall season, occurring on 20 and 21 Oct., had reduced turf color below an aesthetically acceptable level (color of 6.0) for all N treatments by 2 Nov. However, color responses were still significant for all N sources other than UF for the 'Tiflawn', and MU, NO, and UF for the AZ Common. The first killing frost in 1989 occurred on 4 Nov. and plots were totally browned at this time.

Most N sources improved green color significantly at all rating dates for AZ Common bermudagrass, and for 20 Apr. and 11 May 1990 for 'Tiflawn' (Table 1). The highest color ratings were consistently recorded for AN and SCU for both grasses. These sources provided the most readily available N and a color response was anticipated if N was still present in sufficient quantities in the plant and the soil following winter dormancy. Of all the

water-insoluble N sources applied, SCU was expected to provide the best color response, and this generally was the case. Warmer temperatures, as well as damage to the sulfur coating that may occur during application, accelerate N release from SCU (Allen et al., 1971). Both MU and IBDU improved turf color, but response was somewhat slower than that to SCU and AN early in the spring. The NO and UF treatments consistently produced lower color ratings for both grasses during April. There was a tendency for the spring color responses in NO- and UF-treated plots to improve with warming temperatures, as was previously reported (Barrios et al., 1982; Hummel and Waddington, 1981).

Significantly colder than average temperatures were experienced in Dec. 1989. Soil temperatures at a 5.0-cm depth remained $< 0^\circ\text{C}$ for 6 d at the end of the month (data not shown). Extensive turf loss was anticipated, based on previous research detailing greater winterkill of bermudagrass following late-season N fertilization (Beard, 1982). However, the primary response to N treatment was improved turfgrass color the following spring, as had been observed in other research conducted on 'Tifgreen' bermudagrass at this location and at this time (Goatley et al., 1994). Bermudagrass winterkill on local golf courses, sod farms, and home lawns in the central Mississippi area was quite extensive in 1990 following the severe cold, but many environmental and cultural factors not present at our test location may have contributed to the turf loss in these areas.

Initial fall color ratings in 1990 for all N-treated plots were better than for the control, but the differences were nonsignificant for SCU, UF, and IBDU on 'Tiflawn' and IBDU for AZ Common on 12 Oct. (Table 2). Fall color ratings in 1990 were higher than in 1989, since temperatures were warmer prior to the first rating date and the first light frost did not occur until 26 Oct. As in 1989, both AN- and NO-treated plots had the highest initial color ratings, but AN plots were consistently greener for both grasses across all fall rating dates. As before, UF plots tended to have the lowest color ratings across the evaluation period, while color ratings for MU-, SCU-, and IBDU-treated plots were all somewhere between the control and AN treatments (Table 2). The

combined effects of cooling air temperatures and four light frost events that occurred between 26–30 Oct. had significantly reduced color to lower than acceptable levels by 2 Nov.

In Spring 1991 there was no enhancement in 'Tiflawn' color on 23 Apr. for any N treatment, but AN and NO treatments resulted in significantly greener turf than the control on AZ Common at this date. By 1 May all N-treated 'Tiflawn' plots had greener color than the control, while only AN had significantly improved color in AZ Common. By 15 May there were no significant differences in color for any N treatment on either grass (Table 2).

All color responses on 14 Oct. 1991 were significantly better than the control for 'Tiflawn', and the same trend was observed for AZ Common, although differences were nonsignificant (Table 3). However, all ratings were < 6.0 (acceptable color) on 14 Oct. due to two consecutive light frosts on 7 and 8 Oct. Color did not recover for AZ Common, and by 31 Oct. all treatments other than IBDU rated > 6.0 , with the highest mean rating being 7.4 for AN. Only AN-treated plots achieved a color rating on 24 Oct. of at least 6.0 on 'Tiflawn' (Table 3).

In Apr. 1992 there were no significant spring color responses for any N treatment at any rating date on 'Tiflawn'. MU and IBDU treatments improved AZ Common color relative to the control on 13 Apr. (Table 3). By 20 Apr. only IBDU had significantly improved color of AZ Common, but by 27 Apr. all N-treated plots were greener than the control plots, although ratings for AN, NO, and UF were < 6.0 . Spring color response for AZ Common bermudagrass treated with AN was surprisingly low when compared with the previous 2 years' ratings, while on 'Tiflawn' the ratings for AN treatment, although not significantly different from the control, were again among the highest. Since plots were located in the same immediate area, no environmental responses (differences in rainfall, temperature, etc.) can explain the difference in color response.

Total nonstructural carbohydrate levels. The levels of TNC were highly variable for all N treatments across the 3 years on both grasses; however, there were no differences in TNC levels between N treatments except in Dec. 1991, when the IBDU and AN-treated plots

Table 1. Mean fall and spring color ratings of 'Tiflawn' (T) and AZ Common (C) bermudagrass following 29 Sept. 1989 applications of water-soluble and slow-release nitrogen sources.

Nitrogen source ^x	Color ^a											
	Sampling date, 1989–90											
	6 Oct. ^y		20 Oct.		2 Nov.		20 Apr.		27 Apr.		11 May	
	T	C	T	C	T	C	T	C	T	C	T	C
AN	7.5 a	8.0 a	7.0 a	6.5 a	5.5 a	5.0 a	5.8 a	6.8 a	5.0	6.8 a	6.8 a	7.0 a
MU	6.5 ab	6.8 b	6.5 ab	6.3 ab	5.5 a	4.0 bc	5.5 a-c	5.8 ab	5.3	6.3 ab	6.5 a	6.8 a
SCU	6.3 b	6.8 b	6.0 a-c	6.5 a	5.8 a	5.0 a	6.3 a	6.8 a	5.3	6.8 a	7.0 a	7.0 a
NO	7.5 a	6.3 bc	6.5 ab	6.0 ab	5.0 ab	3.8 bc	5.0 b-d	5.0 bc	4.8	6.0 ab	5.5 b	6.5 a
UF	6.3 b	6.0 bc	5.8 bc	5.5 bc	5.5 a	3.5 c	4.8 cd	5.5 b	4.3	6.5 a	5.5 b	6.5 a
IBDU	6.0 b	6.5 b	6.0 a-c	6.0 ab	5.5 a	4.5 ab	5.8 ab	6.0 ab	6.3	6.5 a	6.5 a	7.0 a
Control	5.8 b	5.5 c	5.3 c	5.0 c	4.3 b	3.3 c	4.3 d	4.0 c	5.5	5.5 b	5.5 b	5.5 b

^aVisual color ratings based on a scale of 1 = completely brown, 6 = minimal acceptable color, 9 = dark-green.

^yMean separation within columns by Fisher's protected LSD test ($P \leq 0.05$); absence of letters within a column indicates no significant differences.

^xAN = ammonium nitrate; MU = methylene urea; SCU = sulfur-coated urea; NO = natural organic; UF = ureaformaldehyde; IBDU = isobutylidene diurea; all N sources applied at the rate of 98 kg-ha⁻¹.

Table 2. Mean fall and spring color ratings of 'Tiflawn' (T) and AZ Common (C) bermudagrass following 28 Sept. 1990 applications of water-soluble and slow-release nitrogen sources.

Nitrogen source ^a	Color ²													
	Sampling date, 1990-91													
	12 Oct. ³		19 Oct.		24 Oct.		2 Nov.		23 Apr.		1 May		15 May	
	T	C	T	C	T	C	T	C	T	C	T	C	T	C
AN	8.8 a	9.0 a	8.0 a	7.3 a	8.5 a	7.8 a	5.3 a	5.0 a	6.3	5.6 a	7.3 ab	6.3 a	6.9	6.3
MU	8.3 ab	8.3 ab	7.0 bc	6.8 ab	7.5 b	7.5 a	4.8 ab	4.5 ab	6.3	4.5 b	7.1 b	5.6 b	6.9	6.1
SCU	7.8 a-c	8.3 ab	7.3 ab	7.0 ab	7.3 b	7.5 a	5.3 a	4.5 ab	6.1	5.1 ab	7.4 ab	5.9 ab	7.1	6.1
NO	8.8 a	8.8 ab	6.3 cd	7.0 ab	7.0 bc	7.3 ab	5.5 a	5.3 a	6.0	5.6 a	7.1 b	6.1 ab	6.8	6.3
UF	7.5 bc	8.0 ab	6.0 de	6.5 b	6.3 cd	6.5 bc	5.0 a	4.5 ab	6.1	4.8 ab	7.3 ab	5.8 ab	7.0	6.3
IBDU	7.3 bc	7.8 bc	6.8 b-d	7.0 ab	6.8 bc	8.0 a	5.5 a	5.3 a	5.9	5.1 ab	7.6 a	6.0 ab	6.9	6.3
Control	6.8 c	6.8 c	5.3 e	5.8 c	5.5 d	5.8 c	4.3 b	3.8 b	6.1	4.3 b	6.3 c	5.6 b	6.8	6.1

²Color ratings based on a scale of 1 = completely brown, 6 = minimal acceptable color, 9 = dark-green.

³Mean separation within columns by Fisher's protected LSD test ($P \leq 0.05$); absence of letters within a column indicates no significant differences.

^aAN = ammonium nitrate; MU = methylene urea; SCU = sulfur-coated urea; NO = natural organic; UF = ureaformaldehyde; IBDU = isobutylidene diurea; all N sources applied at the rate of 98 kg-ha⁻¹.

Table 3. Mean fall and spring color ratings of 'Tiflawn' (T) and AZ Common (C) bermudagrass following 30 Sept. 1991 applications of water-soluble and slow-release nitrogen sources.

Nitrogen source ^a	Color ²											
	Sampling date, 1991-92											
	14 Oct. ³		24 Oct.		31 Oct.		13 Apr.		20 Apr.		27 Apr.	
	T	C	T	C	T	C	T	C	T	C	T	C
AN	5.5 a	5.4	6.0 a	6.6 a	5.9 a	7.4 a	5.8	4.5 b	7.0	4.3 b	6.5	5.8 bc
MU	5.3 ab	4.5	5.5 ab	5.4 b	5.6 a	6.8 b	6.0	6.3 a	6.8	5.3 ab	6.4	6.3 a-c
SCU	5.6 a	4.5	4.8 cd	5.6 b	5.8 a	6.4 bc	5.5	5.0 ab	6.9	5.3 ab	6.3	6.5 ab
NO	5.5 a	4.6	5.0 b-d	5.5 b	5.8 a	6.6 bc	4.8	5.0 ab	6.9	4.1 b	6.3	5.5 c
UF	4.9 b	4.3	5.3 bc	4.8 bc	4.8 b	6.0 d	5.0	5.0 ab	6.8	4.5 b	6.5	5.8 bc
IBDU	4.8 b	4.5	5.3 bc	4.8 bc	5.8 a	5.6 d	6.5	6.4 a	6.8	6.4 a	6.5	6.9 a
Control	3.8 c	3.8	4.5 d	4.3 c	4.0 b	5.0 e	6.0	4.3 b	6.8	4.3 b	6.4	4.5 d

²Visual color ratings based on a scale of 1 = completely brown, 6 = minimal acceptable color, 9 = dark-green.

³Mean separation within columns by Fisher's protected LSD test ($P \leq 0.05$); absence of letters within a column indicates no significant differences.

^aAN = ammonium nitrate; MU = methylene urea; SCU = sulfur-coated urea; NO = natural organic; UF = ureaformaldehyde; IBDU = isobutylidene diurea; all N sources applied at the rate of 98 kg-ha⁻¹.

had significantly higher rhizome TNC levels than the MU, NO, and control plots (data not shown). The limited differences in TNC levels following late-season N applications on bermudagrass had been previously reported (Goatley et al., 1994).

The high N rates and late application dates were designed to simulate a worst-case scenario in which bermudagrass would have an increased likelihood of winterkill due to late-season growth stimulation, particularly with a water-soluble N source such as AN. An earlier than expected frost event like that of 7 Oct. 1991 limited the desirable color and growth responses from late-season N applications, even though there was some recovery of turf color in this trial, until a killing frost event occurred in November. While bermudagrass growth response to late-season N fertilization will continue to be unpredictable based on the weather, average monthly minimum and maximum temperatures in Oktibbeha Co., Miss., in late fall (average minimum temperatures of 11.0 and 6.2 °C and average maximum temperatures of 24.4 and 18.3 °C for the months of October and November, respectively) still suggest that in most years a positive response can be expected, and this response could help maintain growth and recovery on high-use turfs. Based on an average expected killing frost date of 6 Nov. and the average minimum and maximum temperatures expected in October in Oktibbeha Co., Miss. (Soil survey of Oktibbeha Co., Miss., 1973; C. Wax, personal

communication) we propose that N application at the end of September is reasonable for turf situations in our climate where extended bermudagrass color and growth are desired. Another environmental factor to consider with late-season N applications is rainfall. On average, October is the driest month of the year in Mississippi, with Oktibbeha Co. typically receiving 41 mm (Soil survey of Oktibbeha Co., Miss., 1973). Rainfall for Oct. 1990 was the highest across the 3 years, totaling 33.6 mm vs. 10 mm in 1989 and 24.2 mm in 1991; this was associated with warmer temperatures and the highest turfgrass color ratings from any N treatments.

The 98 kg-ha⁻¹ of water-soluble N applied is twice the recommended rate for a maintenance application during the growing season on bermudagrass (Beard, 1973); a more suitable application rate for AN late in the growing season would be a maximum of 49 kg-ha⁻¹ of N. This N level would reduce both potential N leaching losses and winterkill concerns. The anticipated benefits from application of SRN at 98 kg-ha⁻¹ could be better realized by making applications ≈4 weeks earlier in our area (i.e., 1st week of September), when temperatures are more favorable for bermudagrass growth and color responses. The potential for bermudagrass winterkill is further influenced by the availability of adequate levels of other nutrients, particularly K (Gilbert and Davis, 1971; Juska and Murray, 1974; Miller and Dickens, 1996), as well as a host of other

environmental and soil factors. Dunn et al. (1993) reported that late fall fertilization of zoysiagrass (*Zoysia japonica* Steud.) increased winter weed populations, and a fall preemergence herbicide program, such as used in this research, would likely be required for their control. Still, the overall conclusion from our research is that late-season N applications on bermudagrass did not visibly increase winterkill, but actually enhanced turf greening the following spring.

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