Above Ground Responses of Three Cool-Season Lawn Species to Varying Annual Nitrogen Rates and Application Timings

Kristina S. Walker, Cale A. Bigelow, Douglas R. Smith, George E. Van Scoyoc and Zachary J. Reicher

Objective

To evaluate the above ground responses of the three primary cool-season lawn species to various annual nitrogen (N) programs, including Purdue's current N recommendations, which varied by N-application timing and rate.

Rationale

Lawns are the largest managed turf acreage in the United States. The public generally associates dark-green, dense lawns as those with exceptional turfgrass appearance and quality. Therefore, in order to sustain greenness and promote growth, N is applied at 50-200 kg ha^{-1} yr^{-1} based upon the owner's desired appearance and management intensity. Due to the large acreage occupied by lawns and the perception that most lawns are heavily fertilized (> 150 kg N ha^{-1} yr^{-1}), there is continued public concern regarding N fertilizer misuse. With the exception of evaluating autumn and late season N fertilization practices, information regarding the relative effectiveness of alternative N application timings, rates or various N-programs for lawns is lacking. Additionally, very few studies have directly compared the growth responses of the major cool-season turfgrass species to N-programs under identical field conditions. By carefully evaluating the effects of various annual N-programs, application rates and timings on the above-ground plant responses (e.g. DMY, duration of greenness, and disease incidence and severity), the minimum N requirements that produce moderate DMYs and a turf that remains moderately green and attractive can be determined. These data will assist turfgrass specialists in their efforts to recommend judiciously based N-fertility programs and annual N rates for lawns that maximize turfgrass quality while minimizing mowing needs, disease incidence.

Procedures

A field experiment was conducted from September 2003 through December 2005 at the Purdue University, W. H. Daniel Turfgrass Research and Diagnostic Center, West Lafayette, Indiana. Prior to planting, the entire study area was fumigated with methyl bromide to minimize existing weed competition. Cultivar blends (by weight) of the TTTF, KBG, and PRG were established by seed at rates of 391 kg ha^{-1}, 98 kg ha^{-1}, and 292 kg ha^{-1}, respectively in May 2003. Seed was supplied by Jacklin Seed Co. and the cultivar blends consisted of the following; 'Triple A' TTTF: [Quest (33 %), Pixie (33 %), and Arid III (33%)], 'Premium Sod Blend' KBG: [Absolute (25 %), Rugby II (25 %), Bluemoon (25 %), and Nuglade (25 %)], 'Medalist Gold' PRG; [Monterey II (33 %), Caddieshack (33 %), and Goalkeeper (33%)]. After seeding the entire study area received an application of 73 kg P ha^{-1} from 6-24-24 (N-P-K) and was covered with Agrofabric Pro17 germination blanket (American Agrifabrics, Alpharetta, GA) for 2 wks to conserve moisture, promote germination, and prevent species contamination from adjacent plots.

The N fertilizer programs were initiated on 10 September 2003. Eight N fertility programs were evaluated, which varied by annual N, ranging from 0, 49, 73, 123, and 196 kg N ha^{-1} yr^{-1}, and application timing (Table 1). These programs were classified as: "Low":(49 kg N ha^{-1} yr^{-1}, Sept. or 73 kg N ha^{-1} yr^{-1}, Nov.), "Medium" (123 kg N ha^{-1} yr^{-1}, applied either Apr., May, and July (AMJ), Sept. and Nov. (SN), or Sept., Oct., and May (SOM)), and "High" (196 kg N ha^{-1} yr^{-1}, applied Sept., Oct., Nov., April, and May (SONAM) or Sept., Nov., May, and July (SNMJ)). Nitrogen was supplied either as sulfur coated urea (SCU: controlled-release, 31-0-0), urea (water soluble, 46-0-0) or a 50:50

(w/w) mixture depending on the season of application. The specific N application dates and N-sources are footnoted in the data tables.

Turf response to the N programs was measured through DMY, clipping N concentration and visual ratings. Dry matter yield was determined by harvesting fresh clippings from the entire plot to a height of 6.35 cm using a rotary bagging mower (JS60, John Deere) weekly throughout the growing season. Fresh clippings were oven-dried at 82°C in a forced-draft oven for 72 h and weighed. Initially, an attempt was made to replace the remaining clippings on each plot but this proved impractical because the dried tissue remnants contaminated the newly harvested fresh tissue. A subsample (approximately 10 g) of dried leaf tissue was ground in an UDY Mill (UDY Corp., Ft. Collins, CO) to pass through a 0.5 mm screen. Approximately 0.05 g from each plot was analyzed for tissue N content using the LECO CHN-2000 analyzer (LECO Corp., St. Joseph, MI). There were 8, 26, and 23 clipping harvests for 2003, 2004, and 2005 respectively.

Turfgrass appearance was evaluated using visual ratings and quantifying canopy greenness. Turfgrass quality (TQ) was visually rated weekly throughout the growing season using a 1 to 9 scale, where 1 = completely brown, dead turf, 6 = minimally acceptable lawn turf, and 9 = optimum uniformity, density and greenness. Canopy greenness was quantified using a hand-held reflectance meter (FieldScout CM-1000, Spectrum Technologies Inc.). Five measurements were taken per plot using a systematic grid pattern which measured the four corners and center portions. These five measurements were averaged to produce a single plot measurement and are reported as a color index. Periodically, TQ was impacted by diseases such as dollar spot, *Rhizoctonia* blight, and red thread. When a disease outbreak occurred, the plots were rated for percentage blight on a linear 0 to 100 % scale where 0 = no damage and 100 = complete blighted turf.

Results

When totaled across the entire study and averaged across N-program, TTTF had greater DMY than KBG followed by PRG producing 9,426, 7,750, and 7,011 kg ha^{-1}, respectively (Tables 2). For the individual years, averaged across N-program, TTTF produced higher DMYs than both KBG and PRG in 2004 (Fig.1-3). In 2005 however, the TTTF DMY was higher than KBG which was higher than PRG. The higher DMY for KBG in 2005 compared to PRG was most likely due to substantial, > 50%, losses in PRG stand density due to disease which was reflected in the July – Nov. harvests. For each species, DMY increased with increasing annual N rate. There were, however, some notable exceptions such as the similar DMYs between the low Sept. only N-program and the unfertilized turf. Although TTTF generally produced the highest DMY values, as a species it had the least variation among N-programs. When evaluating the data for each individual study year, 2004 and 2005, and each species, some unique seasonal growth trends emerge. For KBG, DMY ranged from 1785 to 5099 kg ha^{-1} and DMY averaged across N-programs increased from 3187 to 3441 kg ha^{-1} for 2004 and 2005, respectively. This is somewhat surprising since there were fewer harvests in 2005. For PRG, DMYs ranged from 1232 to 3721 kg ha^{-1} and when DMY was averaged across all N-programs a slight, 3022 to 2775 kg ha^{-1} decline was measured between years probably due to the fewer harvests. For the unfertilized PRG turf, however, a substantial decline, 1641 kg ha^{-1} in 2004 to 1232 kg ha^{-1} in 2005, was measured and primarily attributed to disease damage. For TTTF, DMYs ranged from 1872-5443 kg ha^{-1} and like PRG the average annual DMY between years declined slightly from 4333 to 4003 kg ha^{-1}. The unfertilized

TTTF DMY declined from 2615 to 1872 kg ha^{-1} and since disease levels were low for TTTF this drop in DMY can only be attributed to the fewer harvests or possibly the slight effects of soil nutrient depletion associated with the weekly clipping removal.

Canopy greenness varied by species and when averaged across the entire study and N-programs, KBG was the greenest followed by TTTF and PRG with color indices of 454, 401 and 355 respectively (Table 2). For each individual species, canopy greenness generally increased with increasing annual N rate with the high N-programs resulting in the highest values (Fig. 1-3). There were, however, several exceptions such as for KBG where the medium SOM N-program was similar to the high N-programs, ranging from 496-527, and for PRG where the medium SOM and AMJ N-programs were similar to the high N-programs, ranging from 372-402. Lastly, for TTTF all three medium N-programs were similar to the SNMJ high N-program with indices ranging from 407-433. The aforementioned greenness trends were also generally displayed for each individual species in each calendar study year. For KBG in 2004, the two high N-programs and the medium SOM N-program were greenest, with values ranging from 504-578. In 2005, the two high N-programs and the medium AMJ N-programs were greenest, with values ranging from 503-556. For PRG in 2004, the high SNMJ N-program and medium AMJ N-program were greenest, with values ranging 408-448. However, the high N-programs were not different from the medium SOM N-program. In 2005, the high and medium AMJ and SOM N-programs were similar but the medium SOM N-program was not different from the low Nov. only N-program. For TTTF in 2004, all the high and medium N-programs were similar but the medium SOM and SN N-programs were not different from the low Nov. only N-program, 405. In 2005, the high and medium AMJ N-programs produced the greenest turf, with values ranging from 453-476.

In general, greenness was also related to leaf tissue N content which averaged 33.9, 35.2 and 31.5 g kg^{-1} for KBG, PRG, and TTTF, respectively for the entire study period across N-programs (Table 2).

Significant differences among species and to a lesser extent N-program for disease incidence and severity were recorded in both study years (Tables 2, 3, and 4). Turf damage assessed as stand blight was attributed primarily to dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) however, traces of red thread (*Laetisaria fuciformis* (McAlpine) Burdsall) and *Rhizoctonia* blight (*Rhizoctonia solani* Kuhns) were also apparent, but not independently rated because they were visually difficult to discern. In the summer of 2004, disease levels when averaged across all N-programs were relatively low, $\leq$ 6.7 % (Table 3). Among species, TTTF had slightly more blight than KBG, 1-7 %, on three rating dates but was similar to PRG on 12 June and 16 June. Although there were significant species differences, at these low disease levels the differences are probably not practically important. In 2005, significant species differences were again recorded and TTTF and KBG again had relatively low blight levels, 1.0-2.3 %. Perennial ryegrass, however, sustained substantially more (42-81 %) blight compared to 2004 where disease levels were rather low, < 11% (Table 7). Of all the N-programs, the unfertilized and low Sept. only N-program consistently resulted in more blight than the others. It is also important to note that throughout this study no increase in disease incidence due to heavy, 196 kg N ha^{-1} yr^{-1} N-program or spring applied N was observed. When averaged across the entire study and N-programs, TQ ranked TTTF > KBG > PRG with mean values of 7.0, 6.7 and 6.3 respectively (Table 2). Yearly TQ ratings for each species generally followed the seasonal growth pattern for cool season turfgrasses with higher TQ values in the spring, lower values during summer and an improvement in the fall. The superior performance of TTTF over KBG and PRG was primarily due to the more consistent annual appearance during each growing period. Of all three species, KBG was the slowest to green-up resulting in low, ranging from 2.8-6.0, TQ ratings, which would be deemed unacceptable, < 6.0, when rating lawn TQ. In 2005, TTTF resisted summer disease more than PRG resulting in higher TQ ratings. For each species, TQ generally increased compared to the unfertilized plots as annual N > 49 kg N ha^{-1} yr^{-1} (Table 5). For all species on many rating dates the low Sept. only N-program produced TQ ratings similar to the unfertilized plots. The highest TQ values were generally associated with the high N-programs which resulted in the greenest turf . However, some of the medium N-programs also resulted in TQ ratings equivalent to the high N-programs. Examples of these programs include the SOM N-program in 2004 for KBG, the AMJ N-program for PRG in 2004 and the AMJ and SN N-programs for TTTF. For PRG mean annual TQ values for each N-program decreased numerically from 2004 to 2005. This annual decline is attributed to the significant losses in stand density previously described and therefore lower TQ values which this negatively affected TQ ratings well into the autumn months. By contrast for KBG and TTTF, mean annual TQ ratings improved for all N-programs in 2005, except for the unfertilized and low Sept. only N-programs. While the mean annual TQ values for KBG were sometimes lower than TTTF, on many rating dates during active growth the well fertilized, ≥ 123 kg N ha^{-1} yr^{-1}, KBG had the highest TQ values of all three species frequently > 8.0.

Conclusions

Turfgrass specialists throughout the cool-humid region have routinely recommended that ≥ 49 kg N ha^{-1} yr^{-1} should be applied to a cool-season lawn to maximize appearance and growth with an optimum N application, where only a single application is desired, being late-summer (e.g. September 1-15th). If the current goal in lawn management is to be environmentally responsible or maintain lawn turf systems that produce the highest visual appearance with only moderate growth using the fewest N inputs, the results of this study demonstrate that this goal can be achieved by planting an improved TTTF blend and fertilizing with relatively low, 74-123 kg N ha^{-1} yr^{-1}, N levels. Compared to KBG, however, some additional mowing, particularly during the spring months should be expected if TTTF receives ≥ 123 kg N ha^{-1} yr^{-1}. While, KBG appearance often exceeded TTTF on many rating dates, consistent seasonal performance was limited by slow spring green-up relative to both TTTF and PRG and therefore KBG may necessitate higher (≥ 123 kg N ha^{-1} yr^{-1}) annual N levels to optimize TQ. Among species, PRG was the worst performing species and very few differences between N-programs. Although PRG greened up faster in the spring than KBG, it was severely blighted by dollar spot regardless of N program and therefore PRG monostands for moderate to low management intensity lawns in the middle to lower cool-humid region should be avoided. Lastly, if a turf manager desires to apply N only once during the year, a single N application in mid Nov. appears more beneficial than the traditionally recommended Sept. only application in central Indiana, especially for TTTF.

Acknowledgements

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Table 1. Experimental nitrogen (N) programs for three cool-season turfgrass species.

		Monthly Rate					
Application timing†	Annual N rate‡	Apr.	May	July	Sept.	Oct.	Nov.
	---kg N ha^{-1}---						
Sept.	49	---	---	---	49	---	---
Nov.	73	---	---	---	---	---	73
AMJ	123	49	37	37	---	---	---
SN	123	---	---	---	50	---	73
SOM	123	---	25	---	49	49	---
SNMJ	196	---	37	37	49	---	73
SONAM	196	24	25	---	49	49	49
Unfertilized	0	---	---	---	---	---	---

† In 2003, N was applied on 10 Sept. (S), 6 Oct. (O), and 10 Nov. (N). In 2004, N was applied on 10 Apr. (A), 10 May (M), 8 July (J), 8 Sept. (S), 7 Oct. (O), and 9 Nov. (N). In 2005, N was applied on 13 Apr. (A), 13 May (M), 15 July (J), 8 Sept. (S), 7 Oct. (O), and 1 Nov. (N).
‡N was supplied as urea alone in Oct. and Nov., in July sulfur coated urea (SCU) was applied alone, and all other times a 50/50 (w/w) mixture of urea and SCU was applied.

Table 2. Cumulative mean study totals for dry matter yield, canopy greenness, leaf tissue nitrogen (N), disease severity, and turfgrass quality of three turfgrass species averaged across eight N programs and analysis of variance for species and N program.

	2003-2005				
	Dry matter yield	Canopy greenness	Leaf tissue N	Disease severity	Turfgrass quality
	---kg ha^{-1}---	Color index	-----g kg^{-1}-----	Visual rating 0-100 %	Visual rating -----1-9-----
Kentucky bluegrass	7,750 b	454 a	33.9 b	1.1 c	6.7 b
Perennial ryegrass	7,011 c	355 c	35.2 a	13.9 a	6.3 c
Turf-type tall fescue	9,426 a	401 b	31.5 c	2.8 b	7.0 a
Species (S)	***	***	***	***	***
Program (P)	***	***	***	***	***
S * P	NS	NS	NS	NS	NS
Rep	NS	NS	**	*	NS

Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (P=0.05).
*, **, *** and NS refer to significant at the 0.05, 0.01, 0.001 level and non-significant, respectively.

Table 3. Mean disease ratings for three cool-season turfgrasses averaged across eight nitrogen (N) programs.

	Disease severity†					
	2004				2005	
Species	12 June	16 June	23 June		19 July	27 July
	---% blight‡---					
Kentucky bluegrass	1.0 b	1.8 a	1.3 b		1.0 b	1.6 b
Perennial ryegrass	3.0 a	3.3 a	1.1 b		57.8 a	42.7 a
Turf-type tall fescue	2.1 a	6.7 a	2.7 a		2.3 b	1.0 b
Species (S)	**	NS	*		***	***
Program (P)	***	***	***		**	NS
S * P	*	*	NS		NS	NS
Rep	NS	**	NS		NS	NS

†A curative chlorothalonil fungicide application occurred on 22 July, 2004 and 25 July, 2005.
‡Percent blight was visually rated on a linear 0 to 100 % scale where 0 = no damage and 100 = complete blight, dead turf.
Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (P=0.05).
*, **, *** and NS refer to significant at the 0.05, 0.01, 0.001 level and non-significant, respectively.

Table 4. Disease severity of perennial ryegrass as affected by eight nitrogen (N) programs.

		Disease severity‡					
		2004				2005	
Application timing†	Annual N rate	12 June	16 June	23 June		19 July	27 July
	kg ha^{-1}	---% blight§---					
Sept.	49	3.8 a	5.2 abc	4.0 a		81.6 a	63.4 a
Nov.	73	2.7 a	2.3 bc	0.9 ab		62.8 a	41.5 a
AMJ	123	0.6 a	1.1 c	0.1 b		77.6 a	43.0 a
SN	123	7.8 a	10.7 a	4.1 a		61.3 a	24.9 a
SOM	123	7.4 a	7.2 ab	0.2 b		54.5 a	46.7 a
SNMJ	196	1.3 a	1.4 c	0.7 b		41.1 a	32.3 a
SONAM	196	1.2 a	0.6 c	0.4 b		41.0 a	41.6 a
Unfertilized	0	3.1 a	3.0 bc	2.0 ab		68.6 a	50.0 a

†In 2003, N was applied on 10 Sept. (S), 6 Oct. (O), and 10 Nov. (N). In 2004, N was applied on 10 Apr. (A), 10 May (M), 8 July (J), 8 Sept. (S), 7 Oct. (O), and 9 Nov. (N). In 2005, N was applied on 13 Apr. (A), 13 May (M), 15 July (J), 8 Sept. (S), 7 Oct. (O), and 1 Nov. (N).
‡A curative chlorothalonil fungicide application occurred on 22 July, 2004 and 25 July, 2005.
Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (P=0.05).
§Percent blight was visually rated on a linear 0 to 100 % scale where 0 = no damage and 100 = complete blight, dead turf.

Table 5. Visual turfgrass quality ratings for three cool-season lawn species as affected by eight nitrogen (N) programs.

		Turfgrass quality										.
		Kentucky bluegrass				Perennial ryegrass				Turf-type tall fescue		
Application timing‡	Annual N rate	2004	2005	Study mean		2004	2005	Study mean		2004	2005	Study mean
	kg ha^{-1}	-----Visual rating (1-9)†-----										
Sept.	49	5.9 d	6.4 d	6.2 de		6.0 cd	5.5 a	5.9 c		6.3 de	6.3 c	6.3 d
Nov.	73	6.4 cd	6.6 cd	6.4 cd		6.4 bc	6.0 a	6.2 bc		6.5 cd	6.9 b	6.7 c
AMJ	123	6.5 cd	7.1 bc	6.8 c		6.7 a	6.4 a	6.6 ab		7.3 a	7.9 a	7.5 a
SN	123	6.6 bc	7.0 cd	6.8 c		6.4 bc	6.2 a	6.3 ab		7.0 ab	7.4 b	7.1 ab
SOM	123	6.7 abc	7.0 c	6.9 bc		6.7 ab	6.3 a	6.6 ab		6.9 bc	7.2 b	7.0 bc
SNMJ	196	7.2 ab	7.7 ab	7.4 ab		6.8 a	6.5 a	6.7 a		7.0 ab	8.0 a	7.5 a
SONAM	196	7.4 a	7.8 a	7.5 a		6.7 ab	6.5 a	6.7 a		7.1 ab	7.9 a	7.5 a
Unfertilized	0	5.9 d	5.9 e	5.9 e		6.0 d	5.6 a	5.9 c		6.2 e	6.0 c	6.1 d
Species	2004	2005	Study mean									
Kentucky bluegrass	6.6 b	6.9 b	6.7 b									
Perennial ryegrass	6.4 b	6.1 c	6.3 c									
Turf-type tall fescue	6.8 a	7.2 a	7.0 a									
Species (S)	**	***	***									
Program (P)	***	***	***									
S*P	NS	NS	NS									

† Turfgrass quality was visually rated on a 1 to 9 scale, where 1 = completely brown dead turf, 6 = minimally acceptable lawn turf, and 9 = optimum uniformity, density and greenness.

‡ In 2003, N was applied on 10 Sept. (S), 6 Oct. (O), and 10 Nov. (N). In 2004, N was applied on 10 Apr. (A), 10 May (M), 8 July (J), 8 Sept. (S), 7 Oct. (O), and 9 Nov. (N). In 2005, N was applied on 13 Apr. (A), 13 May (M), 15 July (J), 8 Sept. (S), 7 Oct. (O), and 1 Nov. (N).

Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD t-test (P=0.05).

, * and NS refer to significant at the 0.01 and 0.001 level and non-significant, respectively.

Figure 1. Mean DMY and canopy greenness, measured as reflectance, for Kentucky bluegrass fertilized with eight nitrogen (N) programs.

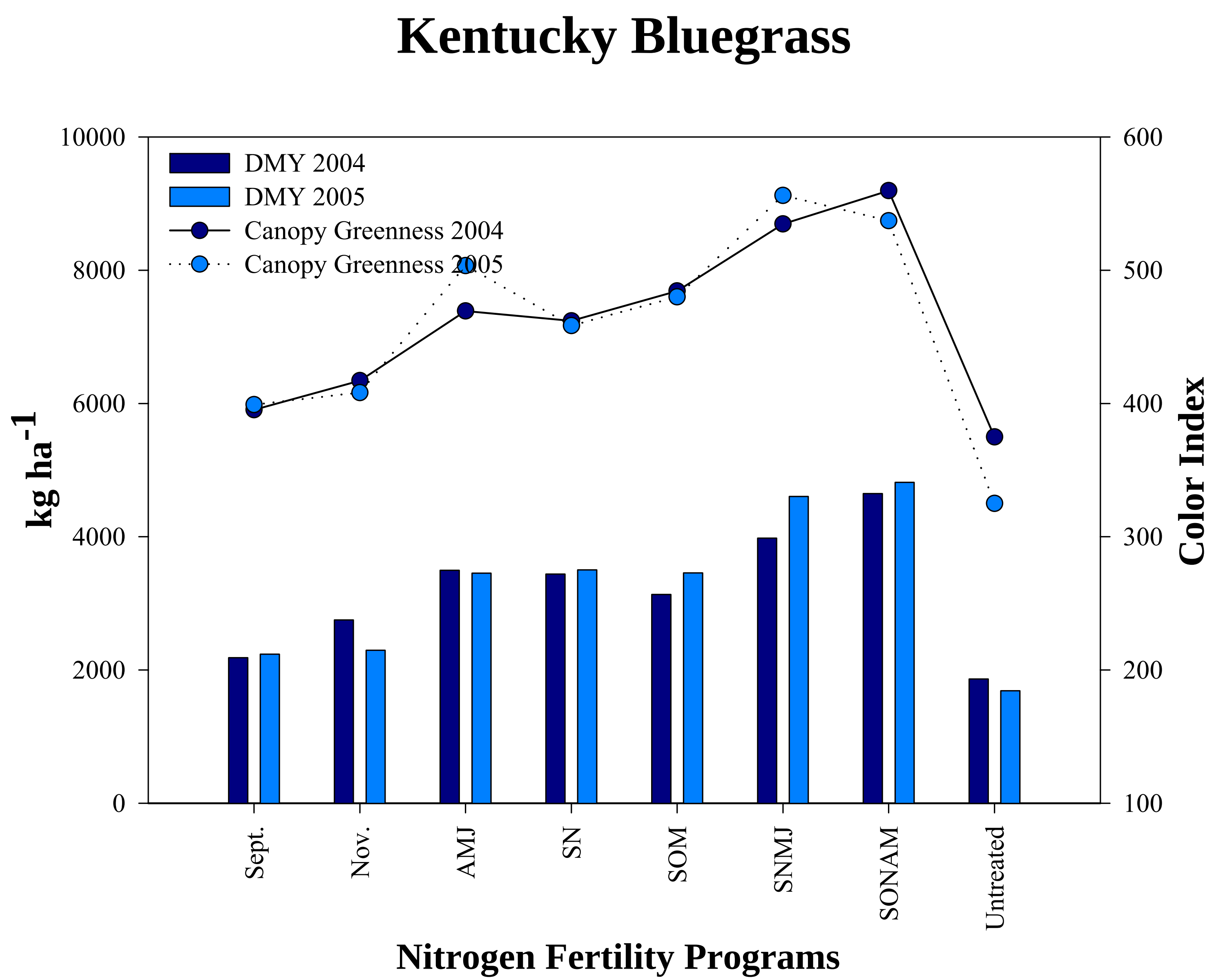

Figure 2. Mean DMY and canopy greenness, measured as reflectance, for perennial ryegrass fertilized with eight nitrogen (N) programs.

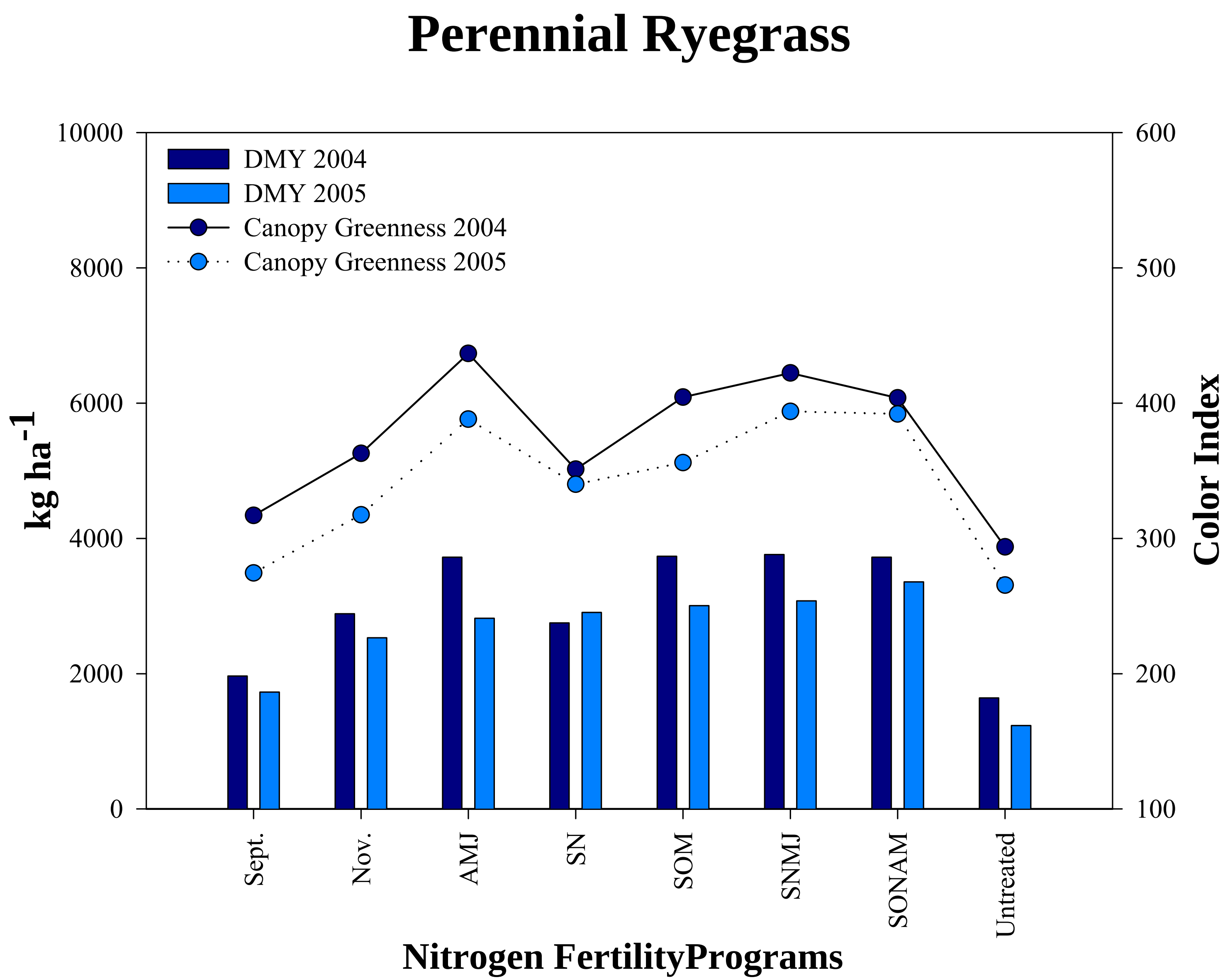

Figure 3. Mean DMY and canopy greenness, measured as reflectance, for turf-type tall fescue fertilized with eight nitrogen (N) programs.