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EFFECTS OF SLOW-RELEASE FERTILIZERS ON TURF QUALITY IN A TURF MIXTURE

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ABSTRACT

A 2-year field study was conducted to determine the influence of the timing of application and different slow release nitrogen (N) sources with different nitrogen rates on the growth and quality of a turfgrass mixture. Three different timings were used for nitrogen application: annually, once every 3 months, and once every 6 months. Three nitrogen sources (ammonium nitrate and two slow-release fertilizers, Entec and Osmocote) were used in the trial. Annually applications were carried out at rates of 0 (control) g m^{-2}, 30 g m^{-2}, 60 g m^{-2}, 90 g m^{-2}. Results of this study showed that both slow-release fertilizers had significantly higher ratings of color and quality and significantly higher clipping yields compared with the control (ammonium nitrate) during the fall and winter seasons. During the other seasons, the slow-release fertilizers produced equal, slightly higher or slightly lower color and quality ratings and clipping yields, compared with the control. It should be noted that an acceptable color rating and turf quality were obtained in the fall and winter seasons with 60 and 90 g N m^{-2} yr^{-1} of slow release fertilizers.

Keywords: Clipping yield, slow-release fertilizer, turf color, turf quality

INTRODUCTION

Cool-season turfgrasses are widely used for home lawns and commercial landscapes in temperate climates. The optimum temperature for shoot growth of cool-season grasses is 15 to 23 °C (Beard, 1973). However, summer temperatures in coastal locations of Turkey having a typical Mediterranean climate often exceed 30 °C. In conjunction with heat stress, drought is often prolonged. Drought or heat stress alone cause a severe decline in turf quality of cool-season grasses (Wehner and Watschke, 1981; Huang et al., 1998). No practical techniques are available for completely eliminating high-temperature stress on turfgrass. A primary consideration is the use of cultural practices that avoid internal plant water deficits by maintaining adequate levels of available soil moisture and water absorption capability (Beard, 1973). Wehner and Watschke (1981) have reported that infrequent irrigation increased heat tolerance in Kentucky bluegrass (Poa pratensis L.), perennial ryegrass (Lolium perenne L.), and annual blue grass (Poa annua L.). However, irrigation rate and frequency can also influence N leaching from turfgrass (Barton and Colmer, 2006). If turfgrass irrigation management has been optimized, further decreases in N leaching may be achieved through improved N fertilizer management. Nutrient release from fertilizers can be influenced by soil pH, soil temperature, microbial activity, moisture content and granular size (Jarrell and Boersma, 1979; Allen, 1984; Turner and Humme,l 1992). Among these factors, temperature is a particularly important stress factor in Mediterranean climates. The timing of fertilizer applications needed to achieve quality turfgrass and minimize N leaching varies with fertilizer type. A range of fertilizer types are used in the production of turfgrass: quick-release inorganic N, slow-release inorganic N and organic N fertilizers. In the maintenance of established turfgrass, the relative effectiveness of these fertilizers varies. Overall, quick-release and slow-release inorganic fertilizers at 100 to 300 kg N ha^{-1} have been shown to effectively maintain turfgrass growth and color (Petrovic, 1990; Turner and Hummel, 1992). Slow-release fertilizers furnish a sustained nutrient supply that improves the efficiency of N fertilizer use and reduces losses from N leaching. Despite these considerable advantages, the use of slow-release fertilizers in horticultural practice is largely limited to turfgrass (Zhang et al., 1998).

The present study sought to investigate the effect of slow-release fertilizers, application time, and rates of N application on turf color and quality and clipping yield.

MATERIALS AND METHODS

The study was conducted in the turfgrass experimental plots of the Uludag University Agricultural Faculty in Bursa, Turkey (40° 15′ North, 29° 01′ East, 70 m above sea level), during 2007-2008 and 2008-2009. The experimental area, located in the transitional zone, has a Mediterranean-type climate. The experimental soil, a sandy loam with a pH of 7.4, was considered rich in potassium (180 kg K ha^{-1}), medium in phosphorus (71 kg P ha^{-1}), and poor in organic matter (0.5%). Treatments were arranged in a split-split plot design with three replications. Application times were designated as main plots, nitrogen sources as subplots, and nitrogen rates as sub-subplots. The sub-subplot size was 1 × 2 = 2 m^2, and the seeding rate was 40 g m^{-2}. A turf mixture of 50% perennial ryegrass (*Lolium perenne* L., cv. Esquire), 30% Kentucky bluegrass (*Poa pratensis* L., cv. Conni) 10% chewing red fescue (*Festuca rubra* spp. *commutata* Gaud., cv. Juliska), and 10% creeping red fescue (*Festuca rubra* spp. *rubra* L., cv. Diego) was used in this study. These percentages are all expressed on a basis of seed weight. The seed mixture was established on October 17, 2006. Seeds were broadcast and top-dressed with a mixture of soil and peat. They were then irrigated as needed to keep the soil surface moist until complete seedling emergence. Irrigation was applied regularly via a rotary sprinkler system to maintain the soil at near field capacity. Tensiometers (Irrometer, Model RA/R-SR) installed at 15- and 30-cm depths were used to monitor soil water tension and irrigation scheduling.

The timing of nitrogen application was varied by using three different application times: annually, 3-monthly, and 6-monthly. Three nitrogen sources were used in this experiment: ammonium nitrate (33-0-0), Entec® (26-0-0+13S) and Osmocote® (22-05-06 + 2 MgO + minor elements). Annually, nitrogen application rates were as follows: 0 g m^{-2}, 30 g m^{-2}, 60 g m^{-2}, 90 g m^{-2}; 3-months: 0.0 g m^{-2}, 7.5 g m^{-2}, 15.0 g m^{-2}, 22.5 g m^{-2}; 6-months: 0 g m^{-2}, 15 g m^{-2}, 30 g m^{-2}, 45 g m^{-2}.

Fertilizer treatments were initiated in mid-March 2007 and were continued for two years. Cuttings were made regularly with a rear-bagging rotary mower at the 4-cm setting when plants were 6-8 cm in height. At each clipping date, a 0.5 × 1.0 m strip through the center of each plot was cut, dried at 70°C for 24 h, and then weighed. During the study, 6 cuttings in spring, 5 cuttings in summer, 4 cuttings in fall, and no cuttings in winter were made, a total of 15 cuttings. Turfgrass color ratings were made on a visual scale of 1-9, where 1=completely yellow and 9=dark green. Turf quality was visually scored (1=poorest; 9=excellent) on each plot during the growing seasons based on turfgrass uniformity, density, and color. Ratings above 7 were considered good, 6 minimally acceptable, and below 5 unacceptable. Normally, color and quality ratings were made for each clipping date. However, very limited top growth occurred from December to February owing to low temperatures. Therefore, the color and quality ratings were made monthly during the winter in order to determine the effect of winter fertilization on the growth, color and quality of the turf mixture. A total of 24 color and quality ratings were taken during this study. On an annual basis, the average temperature for the study period was 14.7°C and average relative humidity was 68%. The long-term annual precipitation was 699.0 mm. Most of the precipitation occurred during winter and early spring. Late-spring and summer rains are limited and erratic in the region of the study.

All data across individual sampling dates were combined for the spring, summer, fall, and winter seasons of both years and were subjected to an analysis of variance using MINITAB (Minitab, Inc. USA, Minitab Release, 12.1). When main or interaction effects were significant ($p < 0.05$), the means were separated using Fisher's least significant difference (LSD) test at the 0.05 level.

RESULTS AND DISCUSSION

The seasons (SE), nitrogen application times (NAT), nitrogen rate (NR), and their two-way and three-way interactions had a significant effect on turf color, quality, and clipping yields, with the exception of the nitrogen sources (NS) factor and SE × NS, SE × NAT × NS, SE × NS × NR interactions (Table 1).

Table 1. Results of variance analysis of turf color, turf quality and clipping yields under seasons (SE), nitrogen application time (NAT), nitrogen sources (NS), and nitrogen rates (NR) across two years (2007-2008 and 2008-2009 growing periods).

Source	Color	Quality	Clipping Yield
SE	**	**	**
NAT	**	**	Ns
NS	ns	ns	Ns
NR	**	**	**
SE x NAT	**	**	**
SE x NS	ns	ns	Ns
SE x NR	**	**	**
NAT x NS	ns	ns	Ns
NAT x NR	**	**	**
NS x NR	ns	**	**
NAT x NS x NR	**	**	**
SE x NAT x NS	ns	ns	Ns
SE x NAT x NR	**	**	**
SE x NS x NR	ns	ns	Ns
SE x NAT x NS x NR	ns	ns	Ns

*,**, ns: Significant at $p = 0.05$ and 0.01, and nonsignificant ($p > 0.05$), respectively.

Spring season had a higher value in terms of color, quality, and clipping yields than the other seasons Application times greatly affected all turf components, except clipping yield. Increasing the rate of N application consistently enhanced the color, quality ratings and clipping yields of the turf during the two years of the study (Table 2).

Table 2. Average turf color and quality ratings (1-9) and clipping yields (g m^{-2}) under seasons (SE), nitrogen application time (NAT), nitrogen sources (NS), and nitrogen rates (NR) treatments across two years (2007-2008 and 2008-2009 growing periods).

	Color	Quality	Clipping Yield
SE			
Spring	7.6 a[1]	7.3 a	414.8 a
Summer	6.7 b	6.1 b	175.8 b
Fall	6.5 c	6.1 b	148.6 c
Winter	4.9 d	4.7 c	0.0 d
NAT			
Annually	6.7 a	6.5 a	757.1
3- Monthly	6.7 a	6.2 b	752.8
6- Monthly	5.9 b	5.4 c	707.2
NS			
Ammonium Nitrate	6.4	6.0	729.7
Entec	6.4	6.1	738.9
Osmocote	6.4	6.1	748.6
NR			
0	4.7 d	4.4	40.0 d
30	6.4 c	6.2	147.6 c
60	7.1 b	6.7	234.0 b
90	7.5 a	6.8	317.4 a

[1]: Mean values of the same column followed by the same letter are not significantly different at 0.05 level using LSD test.

Generally, 3-monthly nitrogen application (3-MNA) produced more uniform turf color, turf quality, and clipping yields than the annually N application (ANA) and 6-monthly N application (6-MNA). However, a gradually decreasing trend in color, quality, and clipping yields was observed from spring to winter for all nitrogen applications. Dramatic decreases in all characteristics were observed in response to NAT along the seasons from spring to winter (Table 3).

Table 3. Turf color and quality ratings (1 to 9), and clipping yields (g m^{-2}) of a turf mixture at seasons and nitrogen application time across two years (2007-2008 and 2008-2009 growing periods). SE x NAT

Nitrogen Application Time	Seasons			
	Spring	Summer	Fall	Winter
	Color			
ANA[1]	7.8 a[2]	6.8 a	5.3 c	3.6 c
3-MNA	7.3 c	6.7 a	6.9 b	5.3 b
6-MNA	7.6 b	6.4 b	7.2 a	5.8 a
	Quality			
ANA	7.6 a	5.7 b	4.9 c	3.4 b
3-MNA	7.3 b	6.3 a	6.5 b	5.3 a
6-MNA	6.9 c	6.3 a	7.1 a	5.4 a
	Clipping yield			
ANA	486.5 a	73.4 b	46.3 c	0.0
3-MNA	411.2 b	229.4 a	176.9 b	0.0
6-MNA	346.5 c	224.3 a	222.6 a	0.0

[1] ANA: Annually Nitrogen Application , 3-MNA: 3 Montly Nitrogen Application, 6-MNA: 6 Montly Nitrogen Application
[2] Mean values within each N source followed by the same letter are not significantly different at 0.05 level using LSD test.

For all nitrogen application times, the lowest color and quality ratings were obtained for the winters. In the spring, the lowest turf color and quality were obtained for the 3-monthly application time, whereas the annual application exhibited the highest turf color and quality ratings in the spring, because greater amounts of fertilizer were applied in March of both years for this treatment (Table 3). The N application rate, source, and timing were all important considerations for single applications. However, an annual N program should be based on the amount of N required to meet plant demands consistently. Generally, N is not applied to maximize the dry matter yield of turfgrass. This procedure would increase mowing frequency. Rather, nitrogen is applied to sustain a dense, healthy turf. Thus, most programs should be specifically designed to moderate the N supply so that turf shoot growth remains at submaximal levels (Bowman, 2003). Only rarely will a single annual N application meet the growth needs or quality expectations for most lawns (Walker et al., 2007). Turf color was found to be more uniform with split applications of N than with infrequent or single heavy N applications (Spangerberg et al., 1986; Wehner and Martin, 1989; Mangiafico and Guillard 2006).

Increasing the rate of N application consistently increased the color and quality ratings of the turf during the two years of the study. Nitrogen treatments significantly affected the ratings of turf color and quality as well as the clipping yields (Table 4). These data are consistent with previous observations on the effect of N fertilization on different turfgrasses (Schou and Tesar, 1977; Sikora et al., 1980; Sills

Table 4. Turf color and quality ratings (1 to 9), and clipping yields (g m^{-2}) of a turf mixture at seasons and nitrogen rates across two years (2007-2008 and 2008-2009 growing periods). SE x NR

Nitrogen Rates	Seasons			
	Spring	Summer	Fall	Winter
	Color			
0	5.7 d[2]	5.6 d	4.3 d	3.2 c
30	7.7 c	6.5 c	6.6 c	4.3 b
60	8.3 b	7.0 b	7.3 b	5.6 a
90	8.6 a	7.6 a	7.7 a	5.7 a
	Quality			
0	5.4 c	4.8 c	4.3 c	3.2 c
30	7.5 b	6.3 b	6.3 b	4.9 b
60	8.0 a	6.6 a	6.9 a	5.3 a
90	8.2 a	6.7 a	7.0 a	5.4 a
	Clipping yield			
0	111.8 d	26.4 d	22.0 d	0.0
30	378.8 c	91.4 c	104.6 c	0.0
60	534.6 b	196.5 b	120.5 b	0.0
90	633.8 a	388.6 a	247.2 a	0.0

[1] ANA: Annually Nitrogen Application , 3-MNA: 3 Montly Nitrogen Application, 6-MNA: 6 Montly Nitrogen Application
[2] Mean values within each N source followed by the same letter are not significantly different at 0.05 level using LSD test.

and Carrow, 1983; Garling and Boehm, 2001). All N applications scored high color and quality ratings in the spring. These results probably reflected the optimum temperature and moisture conditions in the region of the study. Bilgili and Acikgoz (2005) showed that turf color and quality were associated with N fertility treatments and that increasing N significantly enhanced the color and quality ratings of several turf mixtures. In our study, the 60 and 90 g m^{-2} yearly N rates furnished dark-green and high-quality turf, and they provided the highest clipping yields throughout the growing seasons (Table 4). However, the 30 g m^{-2} yearly N rate produced the lowest ratings of turf color and quality, as well as the lowest clipping yields, in all seasons. The control N rate (0 g m^{-2} N) produced unacceptable turf color and quality (rating < 6) in all seasons. Although the 90 g m^{-2} N rate resulted in the darkest green color and the highest quality rating, it also stimulated excessive shoot growth and produced the greatest clipping weight. The second-highest turf color and quality, and the greatest clipping yield were produced by the 90 g m^{-2} N rate during all seasons (Table 4). At increased doses of N, significant differences in the ratings of color and quality and in clipping yield occurred for each N source during each season. A 90 g m^{-2} N rate stimulated excessive shoot growth and produced the greatest clipping weight. The second-highest values were attained at 60 g m^{-2} N rate for all the sampling dates and for the two-year seasonal averages. The plots fertilized with 0 g m^{-2} N rate produced the lowest yields in every case. Although increased N rates were applied during winter, measurements of clipping yield could not be made in winter owing to the dormancy of the turfgrass. Nitrogen fertilization influenced clipping yield at all sampling dates, and only the linear effects were statistically significant. The highest clipping yield was always obtained during the spring. This result was probably the consequence of a natural flush of growth in the spring, the result of the optimal air temperatures for cool-season turfgrasses and the longer days (Beard, 1973; Lawson, 1996). Heat is well known to represent one of the major factors limiting the growth of cool-season grasses during the summer (Jiang and Huang, 2001). During our study, average summer and early-fall temperatures were higher than optimum; therefore, growth declined, and less top growth was produced in summer and early fall. However, seasonal average clipping yields increased 2.5 to 5.0 times in response to the increased rates of N application (30 g m^{-2} to 90 g m^{-2}) during those months. This finding indicates that N fertilization encouraged top growth and improved the color and the quality of the turf during hot days. A similar trend occurred during the winter. Fertilization improved color and quality ratings significantly and produced only negligible top growth during the winter (Table 4). Late-fall and winter N fertilization stimulates winter chlorophyll synthesis and coloration at above-freezing temperatures without shoot growth (Beard, 1973; Powell et al., 1967). It is generally accepted that N fertilization decreases the winter hardiness of turf (Beard, 1973; Wilkinson and Duff, 1972). However, winter injury did not occur in any treatment during the course of this experiment. This result was probably a consequence of the study region's mild winters. The lowest temperatures during the 2007–2009 experimental periods were -5.0°C, -10.4°C, and -8.2°C for each year, respectively. The low temperatures did not injure the turf, even at fertilization rates of 7.5 g m^{-2} monthly during the fall and the winter. These data suggest that fall and winter fertilization improved color and quality in areas having moderate winter temperatures. These data agree closely with the findings of several studies conducted in maritime or transitional regions (Wilkinson and Duff, 1972; Ledeboer and Skogley, 1973; Wehner et al., 1988; Dipaola and Beard, 1992).

Analysis of the interactions of N application times with N rates revealed that the best values of color, quality and clipping yield were obtained during the spring season (Table 5). The N application times x N rates interaction clearly showed that 3-monthly nitrogen applications (3 MNA) produced uniform color and quality ratings throughout the course of the experiment. However, ratings of turf color and quality, as well as clipping yield, decreased dramatically from 90 g m^{-2} N rate to 0 g m^{-2} N rate for the all application times. Waddington and Duich (1976) have likewise found that a single spring application of resin-coated multiple-nutrient fertilizer (SCU) produced unacceptable color in the fall. However a split application improved the turf color rating during the fall to an acceptable level. Additionally, Mangiafico and Guillard (2006) have reported that applying water-soluble N at 49 kg N ha^{-1} from 15 October to 15 December yielded improved turf color and density, compared with a September-only N application. Clipping yields varied greatly, depending on the application time. For all N rates, the 3-MNA application resulted in higher total clipping production than did the ANA and 6-MNA applications.

Table 5. Turf color and quality ratings (1 to 9), and clipping yields (g m^{-2}) of a turf mixture at different nitrogen application time and nitrogen rates across two years (2007-2008 and 2008-2009 growing periods). NAT x NR

Nitrogen Application Time	Nitrogen Rates 0	30	60	90
	Color			
ANA	4.7 d[1]	5.8 b	6.3 b	6.7 b
3-MNA	4.7 d	6.8 a	7.5 a	7.9 a
6-MNA	4.8 d	6.6 a	7.4 a	7.9 a
	Quality			
ANA	4.4 c	5.5 b	5.8 b	5.9 b
3-MNA	4.3 d	6.7 a	6.9 b	7.1 a
6-MNA	4.5 d	6.5 a	7.3 a	7.7 a
	Clipping yield			
ANA	51.2 d	151.6 c	230.0 b	324.4 b
3-MNA	32.0 d	145.2 c	240.0 a	335.5 a
6-MNA	37.1 d	146.0 c	231.6 b	292.3 c

[1] Mean values within each N source followed by the same letter are not significantly different at 0.05 level using LSD test.

The application times × N source × N rates interactions clearly showed that color and quality ratings increased with increasing N rates in all application times of all N sources (Table 6). The 90 g m^{-2} N rate of all N sources had higher turf color and quality ratings than the other N rates in all application times. The highest turf color ratings were obtained from the 90 g m^{-2} N rate in 3-MNA for Osmocote (8.1). Control plots had the lowest color (4.6) and quality ratings (4.3). In contrast, the clipping yield was highly variable and was dependent on the N rate. Very little topgrowth was observed in control plots in all application times. The control plots averaged only 40.1 g m^{-2} of clipping yield. Plots treated with the 60 and 90 g m^{-2} N rates produced significantly higher clipping yields than 30 g m^{-2} N rates. Despite statistically significant differences between nitrogen sources, variation among averages were not large for the characters measured (Table 6). Both slow-release fertilizers and ammonium nitrate produced similar turf-color and turf-quality ratings. However, the slow-release fertilizer was more effective in the fall and the winter than in the spring and the summer. Barton et al. (2006) have reported that the controlled-release fertilizer tended to provide better color than the water-soluble fertilizer during the winter months. Our study revealed a similar trend. In the maintenance of established turfgrass, applying water-soluble fertilizers sparingly and frequently has been found to provide consistent growth and color similar to that achieved by applying slow-release fertilizers less frequently, but at similar total N application rates (Engelsjord and Singh, 1997; Snyder et al., 1981, 1984). According to Barton et al. (2006), no studies of the relative effectiveness of water-soluble and slow-release fertilizers for turfgrass production have previously appeared in the scientific literature. Application of the controlled-release fertilizer offered no agronomic advantage. Growth of turfgrass can be enhanced by using water-soluble or control-release fertilizers if the timing of the applications is based on the solubility of the fertilizer and the demands of the turfgrass for N.

Season × application time × nitrogen rates interactions indicated that color and quality ratings and clipping yield were highly variable within a season and dependent on the application time and N rates (Table 7). In the spring, 60 and

Table 6. Turf color and quality ratings (1-9) and clipping yields (g m^{-2}) of a turf mixture at nitrogen application time nitrogen application time (NAT) x nitrogen source (NS) x nitrogen rates (NR) interaction across two years (2007-2008 and 2008-2009 growing periods). NAT x NS x NR

NR	NAT								
	ANA			3-MNA			6-MNA		
	NS								
	AN[1]	E	O	AN	E	O	AN	E	O
	Color								
0	4.7 h	4.7 h	4.6 h	4.6 e	4.7 e	4.6 e	4.7 f	4.8 f	4.7 f
30	5.8 g	6.0 f	5.8 g	6.8 d	6.7 d	6.9 e	6.6 e	6.6 e	6.7 e
60	6.2 e	6.4 de	6.4 cd	7.5 c	7.5 c	7.4 c	7.2 d	7.5 c	7.3 d
90	6.8 a	6.6 bc	6.6 b	7.8 b	7.8 b	8.1 a	7.8 b	8.0 a	7.9 ab
	Quality								
0	4.5 f	4.4 f	4.4 f	4.3 e	4.4 e	4.3 e	4.5 d	4.5 d	4.6 d
30	5.4 e	5.7 bc	5.4 de	6.6 d	6.6 d	6.8 cd	6.4 c	6.6 c	6.5 c
60	5.6 cd	5.7 bc	6.1 a	7.2 a	7.0 ab	7.1 ab	7.2 b	7.4 b	7.2 b
90	6.1 a	5.8 b	5.7 bc	6.9 bc	6.9 bc	6.9 bc	7.6 a	7.8 a	7.7 a
	Clipping yield								
0	52.0 f	54.2 f	47.4 f	32.4 e	34.0 e 28.4 g	29.5 e	41.5 f	45.0 f	24.7 f
3	146.0 e	149.4 e	159.0 e	143.5 d	149.5 d	142.8 d	136.0 e	139.4 f	163.3 e
6	257.4 c	224.3 d	208.5 d	243.0 c	248.5 c	228.8 c	227.5 c	233.4 c	234.0 c
9	308.9 b	335.0 a	329.0 ab	328.0 b	308.2 b	370.3 a	273.0 b	295.6 a	308.2 a

Table 7. Turf color and quality ratings (1-9) and clipping yields (g m^{-2}) of a turf mixture at seasons (SE) x nitrogen application time (NAT) x nitrogen rates (NR) interaction across two years (2007-2008 and 2008-2009 growing periods). SE x NAT x NR

NR	SE											
	Spring			Summer			Fall			Winter		
	NAT											
	ANA	3-MNA	6-MNA	ANA	3-MNA	6-MNA	ANA	3-MNA	6-MNA	ANA	3-MNA	6-MNA
	Color											
0	5.7 f	5.6 f	5.7 f	5.5 h	5.5 h	5.8 h	4.3 f	4.3 f	4.3 f	3.2 g	3.1 g	3.2 g
30	8.1 bc	7.4 e	7.6 de	6.3 fg	6.8 de	6.3 g	5.4 e	7.0 c	7.5 b	3.5 f	6.0 c	5.2 d
60	8.7 a	7.9 cd	8.8 a	7.1 c	7.3 c	6.6 ef	5.6 de	7.7 b	8.4 a	3.9 e	6.9 b	6.0 c
90	8.8 a	8.2 bc	8.7 a	8.1 a	7.7 b	7.1 cd	5.9 d	8.5 a	8.7 a	3.9 e	7.3 a	7.0 ab
	Quality											
0	5.5 g	5.2 g	5.5 g	4.8 e	4.7 e	5.0 e	4.3 e	4.3 e	4.4 e	3.2 e	3.2 e	3.2 e
30	7.9 cd	7.2 f	7.3 ef	5.5 d	6.7 ab	6.5 b	5.0 d	6.8 c	7.1 bc	3.5 de	6.0 b	5.2 c
60	8.4 ab	7.6 e-f	8.1 bc	6.0 c	7.0 a	6.8 ab	5.2 d	7.3 b	8.2 a	3.7 d	6.5 a	6.0 b
90	8.4 ab	7.6 de	8.5 a	6.5 b	6.7 ab	7.0 a	5.0 d	7.4 b	8.6 a	3.5 de	6.5 a	6.7 a
	Clipping yield											
0	150.6 g	86.0 h	100.0 gh	34.5 ef	19.8 f	25.0 ef	19.4 f	22.0 f	24.5 f	0.0	0.0	0.0
3	503.2 c	274.5 f	358.8 e	71.6 ef	150.5 d	52.0 ef	31.2 f	156.1 d	174.0 d	0.0	0.0	0.0
6	630.6 a	448.3 d	524.8 bc	241.0 c	274.6 c	73.8 e	48.5 ef	237.4 c	328.0 ab	0.0	0.0	0.0
9	661.5 a	577.2 b	662.8 a	550.1 a	472.8 b	142.4 f	85.8 e	292.0 b	363.5 a	0.0	0.0	0.0

90 g m^{-2} N rates of ANA and 6-MNA fertilization regimes produced significantly higher color and quality ratings. Superior color and quality ratings were obtained in 3-MNA and 6-MNA fertilized plots in fall season when the rates of 90 g m^{-2} N rates were applied. Turf quality ratings generally followed the seasonal growth pattern for cool-season turfgrass, with higher turf quality ratings during the spring, lower values during the summer, and an improvement in the

fall (Walker, 2006). In this study, the control plots produced low clipping yields in all seasons and application times. In control plots, an average clipping yields of 112.2, 26.4, 22.0 and 0.0 g m^{-2} were obtained in spring, summer, fall and winter seasons, respectively. Except in the winter, the clipping yield increased with an increase in the N rate in all of the seasons, and the maximum yields were obtained at an N rate of 90 g m^{-2} N rates with ANA and 6-MNA in spring season. The ANA and 6-MNA fertilization regimes produced significantly higher clipping yield during the spring than did the 3-MNA application. The lowest clipping yields were obtained from the 6-MNA application during the summer, owing to the dramatic decrease in nitrogen effectiveness. However, this application produced flushes of growth shortly after fertilization occurred in the fall. The highest clipping yield was always obtained during the spring. This result is probably the consequence of a natural flush of growth during the spring, a response to the optimal air temperature for cool-season turfgrasses and the longer days (Beard, 1973; Lawson, 1996). Heat is well known to be one of the major factors limiting the growth of cool-season grasses during the summer (Jiang and Huang, 2001). During our study, the average temperatures during the summer and the early fall were higher than the optimum. Therefore, growth declined, and less top growth occurred during the summer. During both experimental years, the clipping yield could not be measured during the winter, owing to the dormancy of the turfgrass (Table 7).

CONCLUSION

Results of this study showed that both slow-release fertilizers had significantly higher ratings of color and quality and significantly higher clipping yields compared with the control (ammonium nitrate) during the fall and winter seasons. During the other seasons, the slow-release fertilizers produced equal, slightly higher or slightly lower color and quality ratings and clipping yields, compared with the control.

A single spring application of ammonium nitrate produced unacceptable turf color and quality in the fall and winter, but a split application improved turf color and quality in the fall and winter to an acceptable level. Without exceptions among N sources and N application times, the highest N rate always gave the darkest colored turf.

In most cases, no obvious differences were found between equal doses of the slow-release fertilizer and the control chemical AN fertilizer. Based on our observations, N applications at 7.5 to 15.0 g m^{-2} every 3 months greatly improved the color and the quality of the turf.

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