Journal of Plant Nutrition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lpla20

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Published online: 25 Jun 2013.

Journal of Plant Nutrition, 36:1533–1548, 2013

ISSN: 0190-4167 print / 1532-4087 online
DOI: 10.1080/01904167.2013.799183

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□ *The current study addresses the effects of topdressing composted chicken manure on established turf and comparing the composted chicken manure to a chemical nitrogen (N) fertilizer. Turf color, quality and clipping yields were correlated with N sources and application timing. Monthly fertilization resulted in a more uniform color and turf quality and less clipping yields than did comparable amounts of all N sources applied each as a single application in spring and spring and fall (S + F). The monthly and/or S + F topdressing of chicken manure composts increased the color and quality ratings of the turf mixture during the growing season but did not greatly affect the clipping production.*

Keywords: nitrogen fertilization, chicken manure, composts, turf, color, quality, clipping yield

INTRODUCTION

Nitrogen (N) fertilizers significantly affect turfgrass color and quality based on uniformity, density, color and the absence of weeds (Beard, 1973). Several N application studies have been conducted to determine its effects on the quality, growth and development of Kentucky bluegrass (Spangenberg et al., 1986; Moore et al., 1996) and turf mixtures (Oral and Acikgoz, 2001). In general, N fertilization significantly increases the color, quality (Garling and Boehm, 2001) and clipping yield (Bilgili and Acikgoz, 2005). Nitrogen application timing is influenced by many factors, including the intended use, species, cultivar, climate and soil conditions (Ledeboer and Skogley, 1973; Lawson, 1996). Several studies have compared the timing and rate of N application to determine their effects on the quality, growth and development of different turfgrass species (Moore et al., 1996).

Received 30 November 2010; accepted 13 September 2011.
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Frequent N applications from spring to fall are widely practiced to maintain acceptable levels of color and quality for cool-season turfgrasses (Ledeboer and Skogley, 1973; Wehner and Martin, 1989).

Recently, there has been a renewed interest in the use of animal waste and biosolids as organic N sources in turfgrass management. They are considered to be an alternative form of slow-release fertilizers, and also, organic N sources improve the physical, chemical and biological properties of soil (Angle, 1994; Nelson and Craft, 2000). On established turf, composts have been shown to increase the growth, color and foliar N concentrations of low-cut golf fairways (Garling and Boehm, 2001), increase overall turfgrass quality and color (Johnson et al., 2006), reduce the severity of leaf rust caused by *Puccinia* spp. (Loschinkohl and Boehm, 2001) and *Drechslera* spp. (Chandran et al., 2005) and suppress snow mold diseases (*Microdochium nivale* and *Typhula* spp.) caused by creeping bentgrass (Boulter et al., 2002). Despite the existence of several studies on the effects of animal waste and bio-solids on turfgrasses, limited published data are available regarding the effects of using composted chicken (*Gallus gallus*) manure as a topdressing material. Barton et al. (2006) indicated that water-soluble and control-release chemical N fertilizers produced better shoot growth and color than pelletized poultry manure in *Cynodon dactylon* sod. The nitrogen use efficiency of the poultry manure was also much lower than that of inorganic fertilizers.

The objectives of this study were to evaluate the effects of topdressing composted chicken manures on established turf and to compare composted chicken manures and chemical N fertilizers applied at different rates and times on the growth and quality of a turf mixture, consisting of three cool-season species.

MATERIALS AND METHODS

The study was conducted at the turfgrass experimental plots at the Uludag University Agricultural Faculty in Bursa, Turkey between 2006 and 2009. The experimental area is located in the transitional zone. The average annual temperature and humidity during the study period was 14.7°C and 68%, respectively. The normal annual precipitation for the study site is 700 mm. Most of the precipitation occurs in the winter and early spring. Late spring and summer rain are limited. The upper 20 cm layer of soil on the experimental site was a sandy loam considered rich in potassium (250 kg K ha^{-1}), medium in phosphorus (25.3 kg P ha^{-1}) and poor in organic matter (0.14%) with a pH of 7.9. The soil was tilled, leveled and rolled during the summer months. Before seeding, 200 kg P ha^{-1} and 100 kg K ha^{-1} were incorporated into the seedbed.

In this field trial, the experiment was set out as a split-split plot design with three replications. Nitrogen sources were varied in the main plots, application times in the subplots and nitrogen rates in the subsubplots. The main plot size was 4 × 18 m, the subplot size was 4 × 6 m and the subsubplot size was 1 × 2 m. The turf mixture was 50% 'Esquire' perennial ryegrass (*Lolium perenne* L.), 30% 'Conni' Kentucky bluegrass (*Poa pratensis* L.), 10% 'Juliska' Chewings fescue (*Festuca rubra* var. *commutata* Gaud.) and 10% 'Diego' creeping red fescue (*Festuca rubra* var. *rubra* L.) by weight. The mixture was sown on 17 October 2006, using a seeding rate of 40 g m^{-2}. The seeds were broadcasted and topdressed with a mixture of soil and peat (50:50), then irrigated as needed to keep the soil surface moist until the complete seedling emergence. Irrigation was applied regularly via a rotary sprinkler system to maintain the soil at near-field capacity. Tensiometers (Model RA/R-SR; Irrometer, Riverside CA), installed at 15- and 30-cm depths, were used to monitor the soil water tension and irrigation scheduling.

Two composted chicken manures, "Organica" [Chicken manure-I (CM-I)] and "Natural Plant" [Chicken manure-II (CM-II)] and ammonium nitrate (AN) were used in the trials. "Organica" was provided by Keskinoglu Poultry Industry, Akhisar, Turkey, and "Natural Plant" was obtained from Seker Poultry Industry, Bandirma, Turkey. Both manures were dry, screened formulations (12 to 20% moisture), containing 3% N, 3.0 to 3.7% P, 3% K, with a pH of 6.8. The ammonium nitrate contained 33% N.

Nitrogen was applied at total annual rates of 0, 30, 60 and 90 g m^{-2}, with three application times: monthly (M), spring + fall (S + F) and single spring (SS). Nitrogen application rates were M (0, 2.5, 5.0 and 7.5 g m^{-2}), S + F (0 + 0, 15 + 15, 30 + 30 and 45 + 45 g m^{-2}) and SS (0, 30, 60 and 90 g m^{-2}). Fertilizer treatments were initiated in the sixth month after the sowing date, i.e., March 2007, and continued for 24 months.

Plots were mowed regularly with a rear-bagging rotary mower at a 4-cm mowing height when plants reached 6 to 8 cm in height. During the course of study, there were five cuttings in the spring, four cuttings in the summer, three cuttings in the fall and no cuttings in the winter, for a total of 12 cuttings. To determine shoot growth, the clippings were collected at each cutting date from a 0.5 m × 1.0 m strip through the center of each plot, dried at 70°C for 24 h and then weighed. Visual turfgrass color and quality ratings were taken regularly each month on each plot throughout each growing season. Color ratings were taken, using a scale of 1 to 9, where 1 = completely yellow and 9 = dark green. The turf quality was visually scored (1 = poorest; 9 = excellent) based on the turfgrass uniformity, density and color. Color and quality ratings above 7 were considered good, 6 were minimally acceptable and below 5 were unacceptable. Color and quality ratings were scheduled for each clipping date. However, very limited top growth from December to February occurred because of low temperatures. Thus, no mowing was carried out in either year during this period, and no clipping yield data were collected. However, color and quality ratings were taken monthly during the winter periods to determine the effects of winter fertilization on the growth and quality aspects of the turf mixture.

Initial soil samples were taken just before starting the treatments. At the end of the study, soil samples were collected from each plot, and the samples treated with the same fertilization regimes were mixed well. Chemical analyses of the pooled soil samples were done in triplicate.

Due to significant interactions of the years with the main effects, data from the two different years were analyzed separately for each season in a split-split plot arrangement, using a completely randomized block design. Individual sampling dates were combined into seasons (spring, summer, fall and winter). Wherever significant effects were found, treatment means were separated, using the Least Significant Difference (LSD) test at the 0.05 level. Statistical analyses were performed with the JMP statistical software package (SAS Institute, Cary, NC, USA).

RESULTS

An analysis of variance revealed that the differences in turf color, quality and clipping yields among the nitrogen sources, application times and nitrogen rate treatments were significant in both years. Additionally, all two- and three-factor interactions were significant in both years, with few exceptions (Table 1).

In general, there were no clear trends observed with seasonal mean color and quality ratings between AN and the composted CM for either year. Ammonium nitrate gave significantly higher seasonal mean color and quality ratings and produced higher clipping yields than the composted CM in the spring seasons (Table 2).

The application times greatly affected all turf responses. There was, in general, a gradual decrease in the color, quality and clipping yields observed from spring to winter in all fertilizer regimes. In all applications, the lowest color and quality ratings occurred in the winter. In the spring, the lowest turf color and quality ratings were obtained with the M application in the 2007–2008 season, and no significant differences were noted between application times in 2008–2009, whereas the S + F application generally exhibited the highest overall visual turf color and quality ratings in the fall because greater fertilizer amounts were applied in September of both years for this treatment (Table 2).

Increasing the rate of N consistently enhanced the color and quality ratings of the turf in all seasons and years. In particular, the 5.0 and 7.5 g m^{-2} N rates provided the darkest green and highest-quality turf throughout the growing seasons. The 2.5 g m^{-2} N rate produced minimally acceptable turf color (rating = 6) in four of the eight seasons-years and minimally acceptable quality (rating = 6) in two of the eight seasons-years. Although

TABLE 1 Results of variance analysis of turf color, turf quality and clipping yields under seasons (S), different nitrogen sources (NS), application time (AT), and nitrogen rates (NR), treatments in 2007–2008 and 2008–2009 experimental years

	2007–2008				2008–2009			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
				Color				
Blocks								
NS	**	**	*	**	**	**	ns	**
Main plot error								
AT	**	**	**	**	**	**	**	**
NS × AT	**	**	**	**	**	**	**	**
Sub plot error								
NR	**	**	**	**	**	**	**	**
NS × NR	**	*	**	**	**	**	**	**
AT × NR	**	**	**	**	**	**	ns	**
NS × AT × NR	ns	**	**	**	**	**	**	**
Sub-sub plot error								
				Quality				
Blocks								
NS	**	**	**	**	**	**	**	**
Main plot error								
AT	**	**	**	**	*	**	**	**
NS × AT	**	**	**	**	**	**	**	**
Sub plot error								
NR	**	**	**	**	**	**	**	**
NS × NR	**	**	**	**	**	**	**	**
AT × NR	**	**	**	**	**	**	**	**
NS × AT × NR	**	**	**	**	**	**	**	**
Sub-sub plot error								
				Clipping yield				
Blocks								
NS	**	**	**	—	*	**	**	—
Main plot error								
AT	**	**	*	—	**	**	**	—
NS × AT	**	**	**	—	**	**	**	—
Sub plot error								
NR	**	**	**	—	**	**	**	—
NS × NR	**	**	**	—	**	**	**	—
AT × NR	**	**	**	—	**	**	**	—
NS × AT × ND	**	**	**	—	**	**	**	—
Sub-sub plot error								

*, **, significant at $P \leq 0.05$ and $P \leq 0.01$, respectively; ns = not significant.

the 7.5 g m^{-2} N rate resulted in the darkest green color and highest quality rating, it also stimulated shoot growth and gave the greatest clipping weight, followed by a 5.0 g m^{-2} N rate for all seasons and years. The unfertilized plots gave the lowest clipping yields in every instance (Table 2).

The interactions of nitrogen sources and application times in 2007–2008 and 2008–2009 gave statistically significant color and quality ratings and clipping yields. Chicken manures generally behaved similarly in the spring, fall

TABLE 2 Average turf color and quality ratings (1–9) and clipping yields (g m^{-2}) under different nitrogen sources, application time, and nitrogen doses treatments in 2007–2008 and 2008–2009 experimental years

	2007–2008				2008–2009			
	Color							
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Nitrogen sources								
CM-I	6.8 b[1]	6.4 a	5.1 b	4.3 b	6.4 b	6.2 b	6.3	4.3 b
CM-II	6.7 b	6.2 b	5.0 b	4.3 b	6.3 b	6.2 b	6.3	4.3 b
AN	7.3 a	5.9 c	5.3 a	4.6 a	6.7 a	6.4 a	6.3	5.0 a
Application Time								
M	6.6 c	6.3 a	5.1 b	4.8 a	6.2 b	6.1 b	6.4 b	5.1 a
S + F	6.9 b	5.9 b	6.0 a	4.9 a	6.6 a	6.2 b	6.7 a	4.9 b
SS	7.3 a	6.3 a	4.3 c	3.6 c	6.6 a	6.5 a	5.8 c	3.6 c
Nitrogen Doses								
0.0	6.2 d	5.5 d	3.0 d	3.0 d	4.2 d	4.5 d	4.9 d	3.0 d
2.5	6.9 c	5.9 c	4.8 c	4.1 c	6.5 c	6.2 c	6.1 c	4.3 c
5.0	7.2 b	6.3 b	6.0 b	4.9 b	7.5 b	7.0 b	6.8 b	5.1 b
7.5	7.5 a	6.9 a	6.6 a	5.6 a	7.8 a	7.3 a	7.4 a	5.7 a
	Quality							
Nitrogen Sources								
CM-I[2]	6.2 b	6.3 a	5.0 b	4.3 b	6.1 b	5.5 c	5.9 b	4.3 b
CM-II	6.2 b	6.0 b	5.0 b	4.3 b	6.1 b	5.7 b	5.9 b	4.3 b
AN	6.9 a	5.6 c	5.2 a	4.8 a	6.8 a	5.9 a	6.1 a	4.8 a
Application Time								
M	6.1 c	6.3 a	5.3 b	5.1 a	6.2 b	5.8 b	6.1 b	5.1 a
S + F	6.3 b	5.8 b	5.9 a	4.8 b	6.4 a	5.4 c	6.4 a	4.8 b
SS	6.8 a	5.9 b	4.1 c	3.5 c	6.3 ab	6.0 a	5.3 c	3.1 c
Nitrogen Doses								
0.0	5.4 d	5.3 d	3.0 d	3.0 d	3.9 d	3.5 d	4.3 d	3.0 d
2.5	6.4 c	5.9 c	4.9 c	4.3 c	6.4 c	5.9 c	5.9 c	4.3 c
5.0	6.9 b	6.2 b	5.9 b	5.0 b	7.3 b	6.6 b	6.6 b	5.0 b
7.5	7.1 a	6.5 a	6.5 a	5.5 a	7.6 a	6.9 a	7.1 a	5.5 a
	Clipping yield							
Nitrogen Sources								
CM-I	207.4 b	76.0 a	36.3 b	0.0	70.5 c	85.4 b	69.1 b	0.0
CM-II	168.5 c	24.4 c	28.1 c	0.0	98.0 b	80.9 c	58.0 c	0.0
AN	390.7 a	68.9 b	105.2 a	0.0	257.3 a	152.9 a	100.2 a	0.0
Application Time								
M	150.3 c	66.0 b	56.4 b	0.0	98.3 c	118.8 b	81.2 b	0.0
S + F	268.7 b	34.3 c	85.3 a	0.0	142.2 b	78.0 c	91.2 a	0.0
SS	347.5 a	69.0 a	28.1 c	0.0	185.4 a	121.7 a	54.9 c	0.0
Nitrogen Doses								
0.0	117.9 d	13.8 d	10.1 d	0.0	18.9 d	8.3 d	17.2 d	0.0
2.5	239.3 c	34.7 c	45.4 c	0.0	125.6 c	64.5 c	69.2 c	0.0
5.0	305.8 b	65.3 b	69.5 b	0.0	179.4 b	139.3 b	96.8 b	0.0
7.5	359.1 a	111.9 a	101.4 a	0.0	243.9 a	213.5 a	119.9 a	0.0

[1]Means within an individual season-year followed by different letters are significantly different according to LSD at the 5% level.

[2]CM-I: Chicken manure-I, CM-II: chicken manure-II, AN: ammonium nitrate, M: monthly, S + F: spring + fall, SS: single spring.

and winter seasons for both years. However, there were significant differences between the all CM in terms of the color ratings of the S + F applications in the summer 2007–2008, the SS application in the fall 2008–2009 and the M application in the winter 2008–2009. Similarly, significant differences between the quality ratings of the all CM were noted in the spring 2007–2008 SS, the summer 2007–08 M, the S + F, the SS and the summer 2008–2009 M applications. During the course of the study, AN at varying timings of application generally produced significantly higher ratings and clipping yields in all seasons than the CM, with the exception of the 2007–2008 summer, when CM-I showed superiority in color and quality ratings over AN (Table 3).

With the exception of the 2008–2009 winter, there were no significant differences in color ratings between M fertilizer applications in both years (Table 3). Nitrogen sources behaved differently in terms of clipping yields. Chicken manure did not promote a surge in growth, even with the SS applications. Across two years, mean CM treatment clipping yields of M, S + F and SS fertilizations were 207.3, 228.6 and 316.7 g m^{-2}, respectively. The corresponding values of AN were 442.6, 593.2 and 576.7 g m^{-2}.

The interactions of nitrogen sources and nitrogen rates in the 2007–2008 and 2008–2009 growing periods were statistically significant with regards to the turf color and quality ratings and clipping yields. In general, when N rates increased, significant differences in color and quality ratings and clipping yields occurred at each N source for each season (Table 4). However, the N sources produced different results. Ammonium nitrate encourages top growth, and improved color and quality of the turf was observed for all seasons, particularly the spring. Color ratings increased from 6.1 to 8.0 in 2007–2008 and from 3.6 to 8.2 in 2008–2009, with spring AN fertilization being from 0 to 7.5 g m^{-2}. The effect of AN fertilization levels of 5.0 or 7.5 g m^{-2} on the color and quality ratings was also evident in the summer, fall and winter seasons. Increasing rates of CM fertilization also increased the color and quality ratings, but the increments were smaller than those observed with AN (Table 4).

Average clipping yields for AN fertilization increased approximately 11 times in the spring (57.2 $\rightarrow$ 605.6 g m^{-2}), 8 times in the summer (9.2 $\rightarrow$ 70.6 g m^{-2}) and 59 times in the fall (3.2 $\rightarrow$ 189.6 g m^{-2}) of 2007–2008 and 92 times in the spring (57.2 $\rightarrow$ 605.6 g m^{-2}), 124 times in the summer (2.7 $\rightarrow$ 335.6 g m^{-2}) and 45 times in the fall (3.6 $\rightarrow$ 161.2 g m^{-2}) of 2008–2009, with N rates increasing from 0 to 7.5 g m^{-2}. Clipping yields of both CM were clearly less than for AN fertilization, particularly in the spring. Average clipping yields of the all CM increased only 1.6 times in 2007–2008 (148.3 $\rightarrow$ 235.9 g m^{-2}) and 6.3 times in 2008–2009 (26.1 $\rightarrow$ 164.4), with N rates increasing from 0 to 7.5 g m^{-2} in the spring. Similar trends were seen in the summer and fall (Table 4).

TABLE 3 Turf color and quality ratings (1–9) and clipping yields (g m^{-2}) of a turf mixture at nitrogen sources × application time interaction in 2007–2008 and 2008–2009 growing periods

	Application times											
	Spring			Summer			Fall			Winter		
Nitrogen sources	Monthly	Spring + fall	Single spring	Monthly	Spring + fall	Single spring	Monthly	Spring + fall	Single spring	Monthly	Spring + fall	Single spring
2007–2008												
Color[1]												
CM-I	6.6 *d*[3]	6.7 d	7.1 bc	6.3 ab	6.4 a	6.5 a	5.1 c	5.4 b	4.8 de	4.8 b	4.4 c	3.8 d
CM-II	6.7 d	6.8 cd	6.8 cd	6.1 bc	6.1 bc	6.4 a	5.0 cd	5.4 b	4.7 e	4.7 b	4.3 c	3.9 d
AN	6.6 d	7.3 b	7.9 a	6.3 ab	5.3 d	6.0 c	5.2 bc	7.2 a	3.4 f	4.8 b	5.9 a	3.2 e
Quality[2]												
CM-I	5.9 e	6.0 de	6.7 b	6.3 ab	6.3 ab	6.4 a	4.8 de	5.4 c	4.8 de	4.7 c	4.4 d	3.8 e
CM-II	6.1 de	6.2 cd	6.4 c	6.0 c	6.0 c	6.1 bc	4.9 d	5.5 c	4.6 e	4.6 c	4.3 d	3.9 e
AN	6.4 c	6.9 b	7.3 a	6.5 a	5.3 d	5.1 d	6.1 b	6.7 a	2.9 f	5.8 a	5.6 b	2.9 *f*
Clipping yield												
CM-I	189.3 e	162.9 f	270.1 c	67.6 d	59.1 e	101.4 b	23.7 g	50.1 c	35.3 e	—	—	—
CM-II	104.7 *g*	185.0 e	215.6 d	16.4 h	23.0 g	33.7 f	17.4 h	28.4 f	38.6 d	—	—	—
AN	156.9 f	458.3 b	556.8 a	113.9 a	20.7 g	72.0 c	128.0 b	177.2 a	10.5 i	—	—	—
2008–2009												
Color												
CM-I	6.2 e	6.3 de	6.6 c	6.1 b	6.2 b	6.2 b	6.4 b	6.4 b	6.0 d	4.7 b	4.3 d	3.7 e
CM-II	6.2 e	6.3 de	6.5 cd	6.2 b	6.2 b	6.2 b	6.4 b	6.3 bc	6.2 c	4.5 c	4.2 d	3.8 e
AN	6.2 e	7.3 b	7.6 a	6.1 b	6.2 b	7.0 a	6.4 b	7.3 a	5.1 e	5.9 a	5.9 a	3.0 f

Quality												
CM-I	5.9 de	6.1 cd	6.2 c	5.6 d – f	5.4 f	5.7 c – e	5.9 d	6.2 c	5.7 e	4.7 b	4.3 c	3.7 d
CM-II	5.8 e	6.1 cd	6.3 c	5.9 bc	5.5 ef	5.8 b – d	5.9 d	6.1 c	5.7 e	4.6 b	4.2 c	3.8 d
AN	7.0 b	7.2 ab	7.3 a	6.0 b	5.4 f	6.4 a	6.6 b	7.0 a	4.6 f	5.8 a	5.8 a	3.0 e
Clipping yield												
CM-I	37.9 f	66.2 e	107.4 d	115.7 d	64.2 h	76.1 g	65.3 d	78.7 c	63.4 d	—	—	—
CM-II	58.1 e	71.4 e	164.6 c	87.3 i	46.8 e	108.6 b	45.7 f	76.5 c	51.8 e	—	—	—
AN	198.8 b	288.9 a	284.2 a	155.4 b	123.0 c	180.3 a	132.5 a	118.3 b	49.6 e	—	—	—

[1]Color ratings made on 1–9 basis, 1: completely yellow, 9: dark green.
[2]Quality ratings made on 1–9 basis, 1: poorest, 9: excellent.
[3]Means within an individual season-year followed by different letters are significantly different according to LSD at the 5% level.

TABLE 4 Turf color and quality ratings (1–9) and clipping yields (g m^{-2}) of a turf mixture at nitrogen sources × nitrogen rates interaction in 2007–2008 and 2008–2009 growing periods

N source	Nitrogen rates															
	Spring				Summer				Fall				Winter			
	2007–2008															
	0.0	2.5	5.0	7.5	0.0	2.5	5.0	7.5	0.0	2.5	5.0	7.5	0.0	2.5	5.0	7.5
Color																
CM-I[2]	6.3 e[1]	6.7 d	6.9 cd	7.3 b	5.7 de	6.2 c	6.7 b	7.1 a	3.0 e	4.7 d	6.0 b	6.7 a	3.0 f	4.0 e	4.7 c	5.7 a
CM-II	6.2 e	6.7 d	7.0 b-d	7.1 bc	5.5 de	5.8 d	6.6. b	6.8 ab	3.1 e	4.4 d	6.0 b	6.7 a	3.1 f	4.0 e	4.7 c	5.4 b
AN	6.1 e	7.2 bc	7.7 a	8.0 a	5.4 e	5.6 de	5.7 de	6.7 b	3.0 e	5.4 c	6.1 b	6.5 a	3.0 f	4.4 d	5.3 b	5.7 a
Quality																
CM-I	5.7 f	6.1 de	6.4 cd	6.7 bc	5.7 d	6.2 bc	6.6 ab	6.8 a	3.0 d	4.7 c	5.7 b	6.6 a	3.0 g	4.0 f	4.8 d	5.6 a
CM-II	5.7 f	6.0 ef	6.4 cd	6.7 bc	5.4 d	5.8 cd	6.4 ab	6.5 ab	3.0 d	4.3 c	6.0 b	6.7 a	3.0 g	4.1 f	4.4 e	5.0 c
AN	4.8 g	7.0 b	7.7 a	8.0 a	4.9 e	5.8 cd	5.7 d	6.2 bc	3.1 d	5.8 b	5.8 b	6.1 b	2.9 g	4.7 d	5.3 b	5.5 a
Clipping yield																
CM-I	165.3 h	204.4 f	214.3 f	245.8 d	20.8 h	57.8 e	92.4 c	133.2 b	13.4 j	21.5 h	43.2 f	67.3 d	—	—	—	—
CM-II	131.2 i	127.5 i	189.3 g	225.9 e	11.5 ij	15.2 i	32.8 g	37.9 f	13.7 j	17.9 i	33.5 g	47.4 e	—	—	—	—
AN	57.2 j	386.1 c	513.7 b	605.6 a	9.2 j	31.0 g	70.6 d	164.6 a	3.2 k	96.6 c	131.7 b	189.6 a	—	—	—	—
	2008–2009															
Color																
CM-I	4.4 f	6.2 e	7.1 d	7.8 b	4.6 g	6.1 f	6.8 d	7.1 c	4.9 e	6.0 d	6.7 b	7.5 a	2.9 h	3.9 g	4.6 f	5.5 c
CM-II	4.5 f	6.3 e	7.1 d	7.4 c	4.7 g	6.2 ef	6.8 d	7.1 c	5.1 e	5.9 d	6.8 b	7.4 a	3.0 h	3.9 g	4.5 f	5.3 d
AN	3.6 g	7.1 d	7.9 b	8.2 a	4.1 h	6.4 e	7.4 b	7.7 a	4.6 f	6.3 c	6.9 b	7.4 a	2.9 h	4.9 e	5.7 b	5.9 a
Quality																
CM-I	4.1 g	5.9 f	6.9 e	7.3 cd	3.7 g	5.8 f	6.2 e	6.5 d	4.4 f	5.8 e	6.4 cd	7.1 a	2.8 g	3.8 f	4.5 e	5.6 a
CM-II	4.3 g	5.9 f	6.9 e	7.1 de	3.9 g	5.7 f	6.6 cd	6.8 c	4.3 fg	5.7 e	6.5 c	7.2 a	2.8 g	3.8 f	4.4 e	5.2 c
AN	3.3 h	7.5 c	8.1 b	8.4 a	3.1 h	6.1 e	7.1 b	7.5 a	4.2 g	6.3 d	6.8 b	6.9 b	2.8 g	4.8 d	5.4 b	5.7 a
Clipping yields																
CM-I	18.4 ij	44.2 h	67.7 g	151.8 e	14.2 i	54.6 h	101.3 f	171.3 c	24.8 g	64.0 e	78.8 d	100.0 c	—	—	—	—
CM-II	33.8 hi	64.9 g	116.5 f	177.0 d	7.9 j	67.8 g	114.2 e	133.6 d	18.8 h	37.1 f	77.6 d	98.6 c	—	—	—	—
AN	4.4 j	267.7 c	353.9 b	403.0 a	2.7 k	71.0 g	202.3 b	335.6 a	3.6 i	101.9 c	134.0 b	161.2 a	—	—	—	—

[1] Means within an individual season-year followed by different letters are significantly different according to LSD at the 5% level.
[2] CM-I: Chicken manure-I, CM-II: chicken manure-II, AN: ammonium nitrate.

Interactions of application times and nitrogen rates for both study years were statistically significant in terms of the turf color and quality ratings and clipping yields. Significant increases in the color and quality ratings and clipping yields occurred, with increasing N rates observed across all application times (Table 5). However, those increases varied significantly with application times. In the first spring of the study, unfertilized plots were near the minimally acceptable color and quality ratings. Later, however, all unfertilized plots had significantly lower ratings than those of all N application-time treatment combinations. In the spring seasons of both years, the color and quality ratings were significantly higher after high N rate (5.0 or 7.5 g m^{-2}) applications for the S + F and SS treatments compared to the control and 2.5 g m^{-2} treatments. However, the effects of 5.0 or 7.5 g m^{-2} with the SS treatments on the color and quality ratings included a gradual decrease in ratings by the summer, followed by a rapid decrease in ratings by the fall and winter seasons. The color and quality ratings of the SS treatment were significantly lower than those for the other N fertilization treatments in the winter season. Conversely, M applications showed more uniform color and quality ratings than SS or S + F treatments. In the spring and fall seasons, SS and S + F applications had higher color and quality ratings than M applications. The color and quality ratings of the 5.0 or 7.5 g m^{-2} N rates for the M applications were significantly higher than those of the SS and S + F fertilization regimes in the winter season (Table 5)

Yearly total clipping yields varied due to application times and N rates. The average clipping yields of the control plots were 47.2 and 44.3 g m^{-2} $year^{-1}$ in 2007–2008 and 2008–2009, respectively, regardless of the application times (Table 5). Total clipping yields increased with increasing N rates. The average clipping yields corresponding to the 2.5, 5.0 and 7.5 g m^{-2} N rates were 319.4, 440.6 and 572.4 g m^{-2} $year^{-1}$ in 2007–08, respectively, and 259.3, 415.5 and 577.3 g m^{-2} $year^{-1}$ in 2008–2009, respectively. The total clipping yields and seasonal distributions varied according to the fertilization regimes. In general, SS and S + F fertilizations increased the yields for the application seasons. For example, total clipping yields of the M, S + F and SS fertilizations at the 7.5 g m^{-2} N rate were 427, 573 and 717 g m^{-2} $year^{-1}$ in 2007–2008, respectively, and 529, 583 and 621 g m^{-2} $year^{-1}$ in 2008–09, respectively. The SS fertilization produced 70% and 50% of the yearly total clipping yield in the spring seasons of 2007–2008 and 2008–2009, respectively, whereas much lower and more uniform distributions occurred with the M applications. The corresponding values of M treatments in the spring season were 46% and 31% (Table 5).

The changes in soil characteristics based on the soil samples taken just before starting the treatments and at the end of the study are shown in Table 6. The soil characteristics in the control plots did not appreciably change between the start and end of the study. However, some soil characteristics of the plots fertilized with CM varied significantly, with the exception of pH

TABLE 5 Turf color and quality ratings (1–9) and clipping yields (g m^{-2}) of a turf mixture at application time × nitrogen rates interaction in 2007–2008 and 2008–2009 growing periods

Application Time	Spring				Summer				Fall				Winter			
	Nitrogen rates															
	2007–2008															
	0.0	2.5	5.0	7.5	0.0	2.5	5.0	7.5	0.0	2.5	5.0	7.5	0.0	2.5	5.0	7.5
	Color															
M[2]	6.8 d[1]	6.6 de	6.4 e	6.6 de	5.6 g	6.0 ef	6.5 c	6.9 b	3.1 i	4.4 g	6.1 d	6.7 c	3.0 h	4.1 f	5.4 d	6.6 a
S + f	6.0 f	6.8 d	7.2 c	7.7 b	5.5 g	5.8 fg	6.1 d-f	6.3 c-e	3.0 i	6.3 d	7.1 b	7.6 a	3.0 h	4.6 e	5.6 c	6.3 b
SS	5.7 f	7.2 c	8.0 ab	8.2 a	5.5 g	5.8 fg	6.4 c-d	7.4 a	3.0 i	3.8 h	4.9 f	5.5 e	3.0 h	3.7 g	3.8 g	4.0 f
	Quality															
M	5.6 g	6.0 f	6.4 de	6.5 c-e	5.3 f	6.1 cd	6.7 ab	6.9 a	3.1 f	4.9 d	6.1 c	7.0 ab	3.1 h	4.7 e	5.9 c	6.6 a
S + f	5.4 g	6.3 ef	6.7 b-d	7.0 b	5.2 f	5.9 d	5.8 de	6.4 bc	3.0 f	6.3 c	6.8 b	7.3 a	3.0 h	4.6 e	5.4 d	6.1 b
SS	5.1 h	6.8 bc	7.5 a	7.8 a	5.4 ef	5.8 de	6.1 cd	6.2 cd	3.0 f	3.6 e	4.7 d	5.1 d	3.0 h	3.7 fg	3.6 g	3.8 f
	Clipping yield															
M	125.2 i	106.0 j	174.0 h	196.0 g	17.8 h	44.3 e	80.5 c	121.3 b	13.8 h	33.0 g	66.6 e	110.0 b	—	—	—	—
S + f	129.0 i	265.6 f	303.2 e	377.2 c	17.7 h	25.3 g	38.1 f	55.9 d	7.4 i	87.5 d	105.8 c	140.3 a	—	—	—	—
SS	99.6 j	346.4 d	440.0 b	504.2 a	6.0 i	34.4 f	77.2 c	158.6 a	8.9 i	15.6 h	34.0 g	53.9 f	—	—	—	—
	2008–2009															
	Color															
M	4.2 g	6.1 f	7.0 d	7.6 bc	4.4 h	6.1 g	6.8 e	7.1 cd	5.0 g	6.0 e	7.0 c	7.7 a	3.1 h	4.7 e	5.9 c	6.8 a
S + f	4.1 g	6.7 e	7.7 b	8.1 a	4.4 h	6.1 g	6.9 de	7.3 bc	4.8 g	6.7 d	7.4 b	7.9 a	3.0 h	4.6 e	5.6 d	6.3 b
SS	4.3 g	6.8 de	7.4 c	7.7 b	4.6 h	6.5 f	7.4 ab	7.6 a	4.8 g	5.5 f	6.1 e	6.7 d	3.0 h	3.7 g	3.8 g	4.0 f
	Quality															
M	3.8 f	6.2 d	7.3 b	7.6 a	3.4 g	6.0 d	6.7 bc	7.1 a	4.4 j	5.9 g	6.9 d	7.3 b	3.1 h	4.7 e	5.9 c	6.6 a
S + f	3.9 ef	6.5 c	7.6 a	7.8 a	3.6 fg	5.5 e	6.2 d	6.6 c	4.3 jk	6.6 e	7.1 c	7.7 a	3.0 h	4.6 e	5.4 d	6.1 d
SS	4.1 e	6.6 c	7.1 b	7.3 b	3.7 f	6.1 d	6.9 ab	7.1 a	4.2 k	5.3 i	5.7 h	6.1 f	3.0 h	3.7 fg	3.6 g	3.8 f
	Clipping yields															
M	16.7 j	82.2 h	128.1 f	166.1 e	10.7 h	77.5 f	159.4 d	230.3 a	18.7 j	75.7 g	98.1 d	132.3 b	—	—	—	—
S + f	14.2 j	118.0 g	179.5 d	256.9 b	1.9 i	40.2 g	89.8 e	180.0 b	11.2 k	86.0 e	121.6 c	145.9 a	—	—	—	—
SS	25.7 i	176.4 d	230.4 c	308.9 a	12.1 h	75.7 f	168.6 c	230.3 a	21.7 j	45.8 i	70.6 h	81.6 f	—	—	—	—

[1] Means within an individual season-year followed by different letters are significantly different according to LSD at the 5% level.

[2] M: monthly, S + F: spring + fall, SS: single spring.

TABLE 6 Soil characteristics at the end of the experiment for the nitrogen sources × nitrogen rates interaction.

Nitrogen Sources	N Rates (g m^{-2} $year^{-1}$)	Salt (%)	pH	Lime (%)	P (kg ha^{-1})	K (kg ha^{-1})	Organic Matter (%)	N (%)
Original Soil	0	0.10 c[1]	7.90	4.10	25.3 de	250.0 f	0.90 de	0.144 de
Control	0	0.09 c	7.80	4.50	22.1 e	325.6 ef	1.00 cd	0.160 cd
Chicken manure-I	30	0.12 b	7.66	4.33	40.4 cd	380.0 de	1.13 bc	0.181 bc
	60	0.13 ab	7.60	3.83	61.0 b	503.3 c	1.40 a	0.224 a
	90	0.14 a	7.53	4.40	90.5 a	736.6 a	1.40 a	0.224 a
Chicken manure-II	30	0.12 b	7.76	4.20	26.2 de	390.0 d	1.16 bc	0.186 bc
	60	0.12 b	7.70	4.23	50.9 bc	526.6 bc	1.26 ab	0.202 ab
	90	0.13 ab	7.56	4.23	63.1 b	626.6 b	1.40 a	0.224 a
Ammonium nitrate	30	0.07 d	7.70	4.23	21.6 e	286.6 ef	0.90 de	0.144 de
	60	0.07 d	7.73	5.86	13.5 e	280.0 *ef*	0.80 e	0.128 e
	90	0.06 d	7.73	3.03	9.8 e	250.0 f	1.00 cd	0.160 cd
F test (0.05)		**	ns	ns	**	**	**	**

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

**, significant at $P \leq 0.01$; ns = not significant, $P > 0.05$.

and lime. The CM slightly but significantly increased the percentage of salt ratio. The organic matter, P, K and N concentrations of the soil significantly increased with increasing rates of CM applied. There were no significant differences in those characteristics in the soil fertilized with AN.

DISCUSSION

In this study, N applications clearly encouraged color and quality ratings and shoot growth, and these effects increased with increasing N rates. It is well known that N fertilizers ensure fast and uniform turfgrass growth, acceptable color and quality and high shoot density (Beard, 1973; McCarty, 2001). In close agreement with our studies, turf color and quality were affected by differing N fertility treatments, and increasing N significantly enhanced the color and quality ratings of several turf mixtures compared with an unfertilized control (Sills and Carrow, 1983; Bilgili and Acikgoz, 2005).

The results clearly showed that a 7.5 g m^{-2} N rate stimulated shoot growth and gave the greatest clipping weight followed by 5.0 g m^{-2} at all of the sampling dates and seasonal averages for the two years. The unfertilized plots gave the lowest yields in every instance. In particular, the SS applications of all fertilizers encouraged surge growth in the cooler spring, which resulted in higher color and quality ratings for this season. This was probably a result of optimum temperature and moisture conditions during the spring season. It is well known that the optimum temperature for the growth of cool-season turfgrasses is in the range of 15 to 24°C (Beard, 1973).

Organic fertilizers have been considered to be alternative forms of slow-release fertilizers, providing a long-lasting, organic form of N that is mineralized with time (Angle, 1994; Eghball and Power, 1999). In our study, chemical AN fertilization resulted in significantly greater color and quality ratings and higher clipping yields than organic CM. These differences may be explained by the fact that the readily-soluble AN fertilizer resulted in higher available N in the soil compared with CM, which must be mineralized by soil microorganisms before being available for uptake by turf plants. Our results indicated that the annual clipping production using CM was clearly less than that using AN even with the heavy SS fertilization regime, during the first two years of application. However, this is only after the first two years of application of CM. It would be expected that the clipping response from CM, even at high applications, would be less than AN; this may only be true for the first few years of application and not for conditions where CM is applied on a yearly basis for more than 2 years. It is highly probable that after many years of continuous CM application, these clipping yields would increase due to the mineralization of the previously applied CM.

In our study, turf color and quality were more uniform with M applications of N than with SS or S + F applications. These findings are similar to those reported by Turner and Hummel (1992) and Oral and Acikgoz (2001). Snyder et al. (1984) and Engelsjord and Singh (1997) recommended that quick-release inorganic fertilizers should be applied more sparingly and frequently than control- or slow-release fertilizers to maintain uniform growth and color.

Chicken manures produced lower but more uniform color and quality ratings and clipping yields in heavy S + F and SS applications than AN fertilization. Similarly, in *Cynodon dactylon* L. sod, Barton et al. (2006) indicated that chemical N fertilizers doubled shoot growth and improved turfgrass greenness in comparison with plots receiving pelletized poultry manure or biosolids.

Heat is one of the major factors limiting the growth of cool-season grasses during the summer (Jiang and Huang, 2001). Drought or heat stress alone causes a severe decline in the turf quality of cool-season grasses (Huang et al., 1998a, 1998b). During our study, the average summer and early fall temperatures were higher than optimum; therefore, growth declined and less top growth was produced in the summer and early fall than the spring. In some regions, it is strongly recommended that N fertilization be curtailed or greatly reduced during hot days because of concerns of diseases and surge growth that will reduce stored carbohydrates when photorespiration is occurring in cool-season grasses during hot temperatures. In our study, although the effects of N fertilization in the summer were less than that for the spring and fall, N fertilization encouraged top growth and improved the color and quality of the turf during hot days in the summer without any occurrences of disease or damage to the turf.

Our data suggest that fall and winter N fertilization, using M and S + F application regimes, significantly improves turf color and quality ratings with negligible shoot growth. These data are in close agreement with the findings of several studies conducted in maritime or transitional regions (Ledeboer and Skogley, 1973; Wehner et al., 1988; Dipaola and Beard, 1992). The lowest temperatures during the 2007–2009 experimental periods were −5.0°C, −10.4°C and −8.2°C each year, and these low temperatures did not injure the turf, even that fertilized with 7.5 g m^{-2} monthly during fall and winter.

It is well known that various organic fertilizers improved soil physical and chemical characteristics (Angle, 1994), and application of composted municipal biosolids enhanced soil physical properties (Schnell et al., 2010). In our study, the applied CM had approximately 3% N, P and K with an average of 60% organic matter. As expected, the concentrations of those chemicals increased in the soils fertilized with CM. The soil organic matter, N, P and K% showed consistently increasing trends in the CM treatments, corresponding with increasing rates. Similarly, Soldat and Petrovic (2007) indicated that soil P levels increased substantially after the addition of composted poultry or dairy manures.

CONCLUSION

Dry, screened CM formulations (12 to 20% moisture), containing 3% N, 3.0 to 3.7% P, 3% K with a pH of 6.8, applied to turfgrass can provide acceptable color and quality without the surge growth typical of soluble synthetic N fertilizers. However, higher rates may be needed for the first several years with this organic source to meet quality goals before mineralization can provide the amount of N needed to meet these goals.

ACKNOWLEDGMENTS

The authors gratefully acknowledge funding provided by The Scientific and Technical Research Council of Turkey (Tubitak-105O584 Project Leader: Prof. Dr. Esvet Acikgoz). The authors wish to thank American Journal Experts for editing and English proofreading of the manuscript, and Dr. K. Guillard, University of Connecticut, Storrs, USA for critical reading of the manuscript and his valuable comments.

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