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Efficiency of Different Sewage Sludge on Growth and Turf Quality to Perennıal Ryegrass (*Lolium perenne* L.)

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ABSTRACT

The objectives of this study were to evaluate the effects of organic nitrogen source and nitrogen rates on *Lolium perenne* growth, as well as identify the optimum rates on nitrogen rates for the best turf color, quality and clipping yield. The research study was carried out from March 2015 to April 2016 in twelve month at Agrıcultural Research and Experimental Center of Uludag University, near Bursa (40°11´ N, 29°04´ E). The experiment was set up by split plot design in randomized blocks with three replications. Two different sewage sludge (Penguen and Buski-D.A.A.T), one biogas reactor sludge, one chemical fertilizers (%26 Ammonium nitrate) and four different nitrogen rates (0, 2.0, 4.0 and 6.0 g m^{-2}) were used the experiment. According to the analysis results, sewage sludge were observed high plant nutrients although found to be below the critical level of heavy metal content. Organic nitrogen sources produced the lowest dry matter yield but increased the turf color and quality values. In applied nitrogen doses of 6.0 g m^{-2} gave the best results on turf color, quality and dry matter yield. The study showed that application of sewage sludge at rates as low as 4.0 g m^{-2} is useful to at least as 6.0 g m^{-2} nitrogen dose. Sewage sludge, although less effective than chemical fertilizers, has led to at least as the acceptable levels of turf color and quality. Organic nitrogen source that sludge may be an alternative to chemical fertilizers.

Keywords: *Lolium perenne*, Sewage sludge, Nitrogen, Turf quality, Turfgrass

INTRODUCTION

The safe disposal of sewage sludge is one of the most important environmental problems in the worldwide. Sewage sludge is composed of large quantity organic matters, significant amounts of micronutrients, non-essential trace elements and also harmful matters such as micro pollutants and microorganisms. Use of sewage sludge in agriculture can be very effective and economic sludge disposal technique.

Sewage sludge enables the recycling of valuable components such as organic matter and many plant nutrients. The macronutrients in sewage sludge serve as a good source of plant nutrients and the organic constituents provide beneficial soil conditioning properties (Logan and Harrison, 1995). Moreover, sludge obtain high concentration of organic nitrogen for this reason sludge can be considered a slow-release fertilizer (Davis, 1989; Kocaer et al., 2003).

Sewage sludge is relatively high heavy metal contents so that can potentially cause for the soil pollution and toxic effect on plant growth. Therefore sewage sludge application can cause concern. Excessive application of sewage sludge to soil has been found to increase the bioavailability of heavy metals, but the low doses of sewage sludge did not cause a significant increase in heavy metal concentrations (Singh and Agrawal, 2007). Bilgili et al. (2011) suggested that sun dried sludge obtained from a food processing company's wastewater system can be used an N fertilizer for turfgrass without increasing the risk of contaminating the soil with heavy metals or other chemicals. Turf growth and quality responses were equivalent to those obtained from synthetic, soluble N fertilizers. The observed increase in turfgrass quality was attributed to the presence of sufficient amounts of available nutrients in sewage sludges (Bilgili et al. 2011). The results indicated that the sludge applications significantly increased the turfgrass establishment rate and color (Tesfamariam et al., 2009).

The objectives of this study were to (i) compared of sewage sludge and chemical fertilizers effect for the perennial ryegrass growth (ii) evaluate the impact of sewage sludge on growth of perennial ryegrass, and (iii) identify the optimum rates of sewage sludge for turfgrass production.

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 2015-2016. The experimental area, located in the transitional zone, has a Mediterranean-type climate.

Table 1. Monthly precipitation, mean air temperature, and relative humidity in 2015–2016 growing season and long-term (1975–2014) periods in Bursa.

Months	Temperature (°C)			Precipitation (mm)			Relative humidity (%)		
	2015	2016	Long term	2015	2016	Long term	2015	2016	Long term
January	-	5.2	5.5	-	156	82.9	-	80.4	70.0
February	-	11.2	6.1	-	79.1	70.7	-	75	68.7
March	9.1	11	8.6	78.2	72.4	66.1	79.1	71	67.7
April	11.5	-	13.0	95.6	-	66.0	70.1	-	66.1
May	19.3	-	17.4	36	-	43.4	64.2	-	62.0
June	21.7	-	22.5	37.8	-	36.5	72.0	-	57.8
July	25.5	-	24.8	0.0	-	17.7	60.7	-	56.2
August	26.4	-	24.5	5.6	-	13.8	61.5	-	57.3
Septenber	23.6	-	20.2	98.1	-	40.8	73.2	-	63.8
October	16.4	-	15.0	93.2	-	75.5	83.7	-	68.7
November	12.7	-	10.5	26.4	-	79.9	78.1	-	69.3
December	5.6	-	7.2	3.0	-	100.8	76.6	-	68.7
Total	-	-	-	473.9	307.5	694.1	-	-	-
Average	17.2	9.1	14.6	-	-	-	71.9	75.5	64.7

Annual basis, the average temperature for the study period was 14.6°C and average relative humidity was 64.7%. The long-term annual precipitation was 694.1 mm. Most of the rainfall occurred in winter and early-spring. Late-spring and summer rains are limited in the region of the study.

Sewage sludge samples were collected from the Penguen Food Company, wastewater treatment system of Municipality (Buski) and Sütaş Company Biogas Production Systems Bursa, Turkey. Raw sludge sample was dried for several days on concrete ground in order to achieve microbial stabilization. Sewage sludges were milled for the purpose of homogeneous implementation after dried. Structures of the soil and sludges were determined by analysis of chemical and biological properties. According to the analysis results, sewage sludge were observed high plant nutrients although were found below critical level of heavy metal content. Results of the soil and sewage sludge analysis are summarized in Table 2 and 3.

Table 2. General characteristics of soil and dried sludge sample

Parameters	Soil	Sütaş	Buski	Penguen
pH (1:2.5, soil:water and 1:10, sludge:water)	8,48	7,71	6,79	6,73
Electrical conductivity (µS)	468	2540	4100	6780
% N	0,106	2,46	4,76	4,66
Ammonium-N ($mg.kg^{-1}$)		2,46	4,76	4,66
Total-P %		1,25	0,73	1,87
Available-P ($mg.kg^{-1}$)	30,95	1118,6	2717,3	785,9
Organic C (%)	2,091	63,29	60,4	42,15
C/N		7,35	15,32	5,24
Total Na ($mg.kg^{-1}$)	675	1875	4150	1262,5
Total K ($mg.kg^{-1}$)	5180	4587,5	4437,5	6050
Total Ca (%)	17415	2,49	3,62	2,51
Total Mg ($mg.kg^{-1}$)	15090	8198,8	5375	7768,8
Total Mn ($mg.kg^{-1}$)	788,3	299,6	132,6	625,6
Total Fe ($mg.kg^{-1}$)	36210	5050	8278,8	9211,3

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Table 3. Some heavy metals standards and contents of the soils and dried sludge (mg kg^{-1})

	Standards					
Parameters	Soil	Sludge	Original Soil	Sütaş	Buski	Penguen
Total Pb	300	1200	10,42	3,6	11,8	30,3
Total Cd	3	40	0,148	0,5	0,8	1,4
Total Cr	100	1200	134,0	13,6	43,3	176,4
Total Cu	140	1750	33,48	79,6	67,6	115,3
Total Ni	75	400	97,08	18,0	42,0	93,1
Total Zn	300	4000	54,95	596,0	273,5	578,9

The general properties of the sludge were determined as follows: pH and EC were measured on sludge extract at a sludge/ultrapure water ratio of 1:5 (v/v) using a pH and conductivity meter, respectively (Nilsson et al., 2005 a,b). Organic matter was determined by ashing at 550 0C (Anonymous, 2003), Organic carbon was analyzed by Walkley-Black method (Nelson and Sommers, 1982). Total N was measured using the Kjeldahl method (Nelson and Sommers, 1982). Ammonium-N concentrations were determined in 2 M KCl extracts using indophenols blue method (Solorzano, 1969). Available P was determined by molybdenum blue method (Watanabe and Olsen, 1965). Total cations (Na, K, Ca and Mg) were digested with HNO3 (Berghof MWS 2 DAP 60K) and determined by Eppendorf Elex 6361 model Flame photometer. Available Fe, Cu, Zn, Mn, Cd, Cr, Ni, Pb were extracted with DTPA (0.005M DTPA+0.01M CaCl2+0.1M TEA pH 7.3) (Lindsay and Norwell, 1978) and determined by Perkin Elmer 2100DV ICP OES. The total concentrations of metals were determined after the microwave digestion of the samples with HNO3. (Berghof MWS 2 DAP 60K). P was measured calorimetrically and other elements (Cd, Cr, Ni, Pb, Fe, Cu, Zn, Mn) were analyzed in the extracts using ICP OES (Perkin Elmer OPTIMA 2100 DV).

Treatments were arranged in a split plot design in randomized blocks with three replications. Four nitrogen sources [two different sewage sludge (Penguen and Buski), one biogas reactor sludge and one chemical fertilizers (%26 ammonium nitrate)] were designated as main plots and nitrogen rates (monthly 0, 2.0, 4.0 and 6.0 g m^{-2}) as subplots. The main plot size was 4m× 6m = 24 m^2, the subplot size was 1 × 2 = 2 m^2, the total area of our research was 4m x 24m= 96 m^2 and the seeding rate was 40 g m^{-2}. Perennial ryegrass (*Lolium perenne* L., cv. Esquire), was used in this study.

Irrigation was applied method of the open water surface irrigation system via a rotary sprinkler system once every three days. Therefore Class A pan evaporation was used in this field trial.

Fertilizer treatments were initiated in mid-April 2015 and were continued from april to october (seven months). 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 48 h, and then weighed. During the study, 1 cuttings in spring, 2 cuttings in summer, 1 cuttings in fall, and no cuttings in winter were made, a total of 4 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. The color and quality ratings were made monthly. During this study 12 color and quality ratings were taken.

All statistical analyses were performed via JMP 7.0. When 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

Nitrogen sources (NS), nitrogen rate (NR), had a significant effect on turf color, quality, and clipping yields, with the exception of their two-way interactions (NS x NR) (Table 4).

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Table 4. Results of variance analysis of turf color, turf quality and clipping yields, nitrogen sources (NS), and nitrogen rates (NR) during one years (2015-2016 growing periods).

Sources	1	2	3	4	5	6	7	8	9	10	11	12
	Color											
NS	*	**	**	**	**	**	**	**	**	**	*	ns
NR	**	**	**	**	**	**	**	**	**	**	**	**
NS x NR	ns	ns	ns	ns	*	ns	ns	ns	ns	**	ns	ns
	Quality											
NS	*	ns	*	*	**	*	**	*	**	ns	ns	*
NR	**	**	**	**	**	**	**	**	*	**	**	**
NS x NR	ns	ns	ns	*	**	**	ns	ns	ns	ns	ns	ns
	Clipping Yield											
NS		1			2			3			4	
NR		**			**			**			**	
NS x NR		**			**			**			**	

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

Table 5. Average turf color and quality ratings (1-9) and clipping yields (g/m^{-2}), nitrogen sources (NS), and nitrogen rates (NR) treatments during one years (2015-2016 growing periods).

NS	1*	2	3	4	5	6	7	8	9	10	11	12
	Color											
AN	6.4 a	6.7 a	6.4 a	7.0 ab	6.9 a	6.8 a	5.6 ab	6.1 a	6.0 a	6.0 a	5.8 ab	4.8 ab
Buski	5.9 b	6.3 bc	6.2 a	7.1 a	7.0 a	6.3 b	6.0 a	6.1 a	5.5 a	5.5 b	5.5 ab	4.8 ab
Sütaş	5.8 b	6.1 c	5.8 b	6.2 c	6.2 b	5.9 c	5.5 b	5.4 c	4.7 b	5.1 c	5.2 b	4.3 b
Penguen	6.1 ab	6.6 ab	6.4 a	6.7 b	7.0 a	6.0 bc	5.5 b	6.0 ab	5.7 a	5.9 ab	6.0 a	5.0 a
NR												
0	4.4. d[1]	4.7 d	4.5 d	4.7 d	4.5 d	4.5 c	4.3 d	4.4 d	4.0 d	4.2 d	4.0 d	3.4 d
2 g/m^2	5.7 c	6.1 c	5.9 c	6.5 c	6.5 c	6.0 b	5.4 c	5.4 c	5.0 c	5.2 c	5.1 c	4.2 c
4 g/m^2	6.6 b	7.0 b	6.6 b	7.4 b	7.5 b	6.9 a	6.0 b	6.1 b	6.0 b	6.1 b	6.2 b	5.0 b
6 g/m^2	7.5 a	8.0 a	7.8 a	8.5 a	8.6 a	7.5 a	7.0 a	7.4 a	6.8 a	7.0 a	7.1 a	5.9 a
NS	**Quality**											
AN	6.3 a	6.5	6.2 a	6.5 a	7.0 a	7.0 a	6.2 a	6.0 a	5.3 a	5.4 a	5.5 a	5.9 a
Buski	5.7 b	6.4	5.9ab	6.3 a	7.0 a	6.4bc	5.3bc	5.5bc	5.0 a	5.1ab	5.4ab	5.6 a
Sütaş	6.0ab	6.0	5.5 b	5.8 b	6.1 b	6.0 c	5.0 c	5.3 c	4.2 b	5.0 b	5.0 b	5.2 b
Penguen	6.3 a	6.3	6.1 a	6.4 a	6.7 a	6.9ab	5.5 b	5.9ab	5.4 a	5.2ab	5.4ab	5.5ab
NR												
0	4.5d	4.9 d	4.1 d	4.5 d	5.0 d	4.9 d	3.8 d	4.5 d	3.7 d	3.8 d	3.6 d	3.7 d
2 g/m^2	5.8 c	6.1 c	5.6 c	5.9 c	6.1 c	6.4 c	5.4 c	5.3 c	4.6 c	4.7 c	5.0 c	5.3 c
4 g/m^2	6.5b	6.6 b	6.3 b	6.8 b	7.5 b	7.1 b	6.0 b	6.0 b	5.4 b	5.7 b	5.8 b	6.1 b
6 g/m^2	7.5 a	7.5 a	7.5 a	7.8 a	8.3 a	8.0 a	6.9 a	6.9 a	6.2 a	6.5 a	6.7 a	7.1 a
	Clipping Yield											
NS	1**			2			3			4		
AN	34.0 a			71.4 a			52.8 a			70.8 a		
Buski	22.2 b			32.3 b			28.6 b			33.3 b		
Sütaş	23.2 b			27.3 c			15.5 c			17.9 c		
Penguen	22.1 b			27.4 c			24.6 b			43.0 b		
NR												
0	13.7 d			21.4 d			10.9 d			13.4 d		
2 g/m^2	19.9 c			33.9 c			20.6 c			30.8 c		
4 g/m^2	28.5 b			44.0 b			38.3 b			51.5 b		
6 g/m^2	39.5 a			59.1 a			51.8 a			69.3 a		

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

Visual survey dates at plots;

*Color/Quality: 1)15.05.15, 2)24.06.15, 3)28.07.15, 4)18.08.15, 5)19.09.15, 6)14.10.15, 7)05.11.15, 8)20.12.15, 9)13.01.16, 10)15.02.16, 11)22.03.16, 12)19.04.16

**Clipping Yield: 1)15.05.15, 2)24.06.15, 3)19.09.15, 4)14.11.15

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Nitrogen sources showed different affect all turf components, except first clipping yield. Generally application of nitrogen sources scored high turf color and quality ratings during the experiment. Buski and Penguen nitrogen sources had a higher value in terms of color, quality, and clipping yields than the Sütaş nitrogen sources. Increasing the rate of nitrogen application consistently enhanced the color, quality ratings and clipping yields of the turf during the one years of the study (Table 5). 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 and Carrow, 1983; Garling and Boehm, 2001).

Generally, 6 and 4 g m^{-2} nitrogen rates produced more uniform turf color, quality and clipping yields than 2 g m^{-2} nitrogen rates. Nitrogen rates of 6 and 4 g m^{-2} provided dark-green and high-quality turf. The control rate (0 g m^{-2} N) produced unacceptable turf color and quality (rating < 6) in all seasons. However, a gradually decreasing in color, was observed to winter for all nitrogen rates and the clipping yield could not be measured owing to the turf growth declined. For all nitrogen application times, the lowest color and quality ratings were obtained for the winters. 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). In the spring, the lowest turf color and quality were obtained for the first application time. The highest turf color and quality ratings in the summer and early fall because fertilizer were applied in these season (Table 4). At increased doses of N, significant differences in the ratings of color, quality and in clipping yield occurred for each N rates during each season.

The heavy metal concentrations in the sewage sludge depend on factors that contain both the origin of sewage sludge and sewage sludge treatment processes. The bioavailability of sewage sludge to soil is further influenced by soil properties such as pH, redox potential (Eh), sesquioxide content and organic matter, as well as sludge application rate (Hue and Ranjith, 1994). Sütaş sewage sludge's pH was higher than other sewage sludges. Thus bioavailability of Sütaş was observed to be the lowest.

Bilgili and Acikgöz 2011 reported that 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. In this study showed that organic nitrogen sources provided lowest clipping yield than control chemical ammonium nitrate fertilizer.

CONCLUSIONS

Results of this study showed that all sewage sludge applications is useful as an organic fertilizers for turf production. In applied nitrogen doses of 6.0 g/m^2 gave the best results on turf color, quality and clipping yield. The study showed that application of sewage sludge at rates as low as 4.0 g/m^2 is useful to at least as 6.0 g/m^2 nitrogen dose. In most cases, slight differences were found between equal doses of the sewage sludge and the control chemical ammonium nitrate fertilizer. Sewage sludge, although less effective than chemical fertilizers, has led to at least as the acceptable levels of turf color and quality.

Heavy metal contents were found below the critical levels according to the soil pollution control instructions. Sewage sludge can greatly improve the soil nutrient supply without significantly affecting its heavy metal contents. In addition it provided the waste disposal so environmental benefits can be obtained. Organic nitrogen sources produced the lowest clipping yield but increased the turf color and quality values. Thus economic benefits can be provided. Organic nitrogen source that sludge may be an alternative to chemical fertilizers.

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