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## **Sewage sludge compost in zoysia grass sod production**

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### **ABSTRACT**

This study evaluated whether the use of composted sewage sludge in zoysia grass sod production can partially or completely substitute fertilization based on urea. The experiment was conducted on a sod farm located in Itapetininga, São Paulo State, Brazil. The experimental design was a complete randomized block design with five replications and experimental plots of 5 m<sup>2</sup> in a 2x6 factorial scheme. The first factor was the method of application (single or split), and the second factor was composted sewage sludge fertilization and two controls (no fertilization and a standard dose of conventional fertilizer). The conventional fertilizer (urea) dose corresponds to 300 kg N ha<sup>-1</sup> and the sewage compost doses correspond to 100, 200, 300, and 400 kg N ha<sup>-1</sup>. The experiment began with the liming of the total area at 60 days after the previous harvest of zoysia grass sod. Three methods were used to evaluate sod production: soil cover rate, green color intensity, and leaf analysis. At 212 days after the beginning of the experiment, the compost treatment of 30 Mg ha<sup>-1</sup> (300 kg ha<sup>-1</sup> of N), applied in a single dose, allowed for complete sod formation (100% soil cover rate).

**Keywords:** nitrogen, organic fertilization, soil cover rate, SPAD, turfgrass.

## **Lodo de esgoto compostado na produção de grama esmeralda**

### **RESUMO**

Objetivou-se com este trabalho avaliar se o uso de lodo de esgoto compostado na produção de grama esmeralda pode substituir parcial ou totalmente a adubação com uréia. O experimento foi conduzido em área de produção de grama, localizada em Itapetininga-SP. O delineamento experimental utilizado foi de blocos ao acaso, com cinco repetições e parcelas experimentais de 5 m<sup>2</sup> em esquema fatorial 2x6, sendo o primeiro fator a forma de aplicação, parcelada e não parcelada e o segundo fator a adubação com lodo de esgoto compostado e duas testemunhas (sem adubação e dose usual de adubação inorgânica). A dose de adubo inorgânico foi correspondente a 300 kg N ha<sup>-1</sup> e as doses de lodo de esgoto compostado foram correspondentes a 100, 200, 300 e 400 kg N ha<sup>-1</sup>. O início do experimento ocorreu 60 dias após a colheita dos tapetes de grama esmeralda, com a realização de calagem em área total. Foram utilizados três métodos para avaliar a produção do tapete de grama esmeralda: taxa de cobertura do solo, intensidade de cor verde e análise foliar. Aos 212 dias após o início do experimento, a adubação



orgânica com lodo de esgoto compostado, na dose de 30 Mg ha<sup>-1</sup> (300 kg ha<sup>-1</sup> de N), aplicado de forma não parcelada, permitiu formação do tapete de grama (100% taxa de cobertura do solo).

**Palavras-chave:** adubação orgânica, grama, nitrogênio, SPAD, taxa de cobertura do solo.

## 1. INTRODUCTION

The use of *in natura* or composted sewage sludge as a soil conditioner and source of nutrients for agricultural crops is an alternative disposal method for such waste that is used in several countries (Singh and Agrawal, 2008; Corradi *et al.*, 2016). In Brazil, its use is regulated by Conama Resolution 375 (Conama, 2006), which limits the levels of acceptable pathogenicity for Class A sludge, thus making direct use of sewage sludge in agriculture unviable. However, it is legally possible to compost the sludge by mixing it with a carbon source to produce a Class D Compound Organic Fertilizer Product, according to the Ministry of Agriculture (MAPA) Federal Decree 4.954 of January 14, 2004 and Normative Instructions 23 from 08/31/2005 and 27 from 05/06/2006.

The composting process not only transforms the biodegradable material into humus, but also reduces and deactivates pathogens and reduces the concentration of heavy metals, thus making it adequate for use as a fertilizer to provide nutrients to the soil (Kiehl, 1985; Paredes Filho, 2011; Rashad *et al.*, 2010).

The use of composted sewage sludge in the production of sod grass has previously been analyzed. For example, Angle *et al.* (1981) showed improvements related to quality, post-harvest survival, and the production system for Kentucky bluegrass (*Poa pratensis* L.). Other studies corroborate these results (Schnell *et al.*, 2009; Tesfamariam *et al.*, 2009; Griffith *et al.*, 2017).

Zoysia grass (*Zoysia japonica*) is the main species of grass cultivated in Brazil, and it currently covers approximately 80% of the total production area (Grama Legal National Association, 2017). The species is usually cultivated for use in landscaping projects, sports fields and along highways due to its resistance to drought and trampling, rapid rooting, and its adaptability to a tropical climate (Turfgrass Producers International, 2002; Gurgel, 2003).

Because of its stoloniferous-rhizomatous growth habit, zoysia grass shows high resistance to trampling and an elevated rate of soil cover. According to Li *et al.* (2011), rhizomes and stolons linked to nitrogen fertilization are responsible for the resistance and quality of the sod.

Nitrogen (N) is the most important nutrient in the production of zoysia grass sod and is directly associated with shoot growth, increased green coloration, resistance, and soil cover rate. Although N demand varies with soil type, previous studies have shown that the best responses occur with 408 kg N ha<sup>-1</sup> per year for zoysia grass (Godoy *et al.*, 2007) and 425 kg N ha<sup>-1</sup> per year for Kentucky bluegrass (Griffith *et al.*, 2017).

Composted sewage sludge can present a N concentration of 10 g kg<sup>-1</sup> based on dry matter. As such, it has the potential to fully satisfy the demand for this nutrient without the need for synthetic fertilizers and minerals (Singh and Agrawal, 2008; 2009; Mehrotra *et al.*, 2016) in the production of zoysia grass sod. In addition to being rich in N, and because it presents stabilized organic matter, organic compost has a direct impact on the physical and biological properties of the soil, since part of the applied biosolids will remain in the soil after the sod harvest (Schnell *et al.*, 2009; De Maria *et al.*, 2007).

In this context, this study aims to verify the effects of fertilization with composted sewage sludge on zoysia grass production, with the goal of partially or completely replacing the use of urea fertilization. Thus, herein we test four doses of this organic fertilizer.

## 2. MATERIALS AND METHODS

The experiment was performed from April 2015 to December 2015, in a zoysia grass sod farm (23°91' south latitude and 48°03' west longitude of Greenwich; 636 m altitude), in Itapetininga, São Paulo State, Brazil. The soil in the area is classified as Red Dystrophic Latosol (EMBRAPA, 2006) and the climate is classified as Cfa (subtropical) based on the Köppen-Geiger System (Peel *et al.* 2007), with cold, dry winters, and hot, humid summers (Cunha and Martins, 2009).

We used a randomized block experimental design with five replications and experimental plots of 5 m<sup>2</sup> in a 2x6 factorial scheme, with the first factor including two different methods of application (single or split application), and the second factor being type of fertilization treatment (Figure 1).

Block A				Block B				Block C			
31	d3a2	d3a1	25	19	d1a1	d1a2	13	7	d1a2	d6a2	1
32	d6a2	d2a2	26	20	d2a1	d2a2	14	8	d6a1	d5a2	2
33	d4a2	d1a2	27	21	d3a1	d3a2	15	9	d2a2	d5a1	3
34	d6a1	d1a1	28	22	d4a1	d4a2	16	10	d4a2	d3a2	4
35	d5a1	d4a1	29	23	d5a1	d5a2	17	11	d2a1	d3a1	5
36	d5a2	d2a1	30	24	d6a1	d6a2	18	12	d4a1	d1a1	6

Block D				Block E			
43	d2a2	d4a2	37	55	d4a2	d6a1	49
44	d6a2	d3a2	38	56	d2a2	d3a2	50
45	d1a2	d4a1	39	57	d5a2	d1a1	51
46	d5a2	d1a1	40	58	d1a2	d2a1	52
47	d3a1	d5a1	41	59	d5a1	d4a1	53
48	d6a1	d2a1	42	60	d6a2	d3a1	54

d= Dose

a= Application

**Figure 1.** Graphical schema of experiment.

To assess the effects of fertilization on zoysia grass sod production, the treatments included: urea; sewage sludge compost (SSC) in four different doses (10, 20, 30 and 40 t ha<sup>-1</sup> of compost sewage sludge, dry weight), based on the requirement of N (100, 200, 300 and 400 kg N ha<sup>-1</sup>); and a control (no fertilizer). Four treatments received a single application of the SSC fertilizer and the other treatments included two applications: 50% of the SSC at the beginning of the experiment and a second application after reaching a soil cover rate of 50%. The sewage sludge compost came from the sewage treatment facility in Jundiaí, São Paulo State (Table 1).

**Table 1.** Chemical composition of the sewage sludge compost.

Parameter	Concentration <sup>(1)</sup>
Nitrogen (g kg <sup>-1</sup> )	10.7
Phosphorus (g kg <sup>-1</sup> )	6
Organic Carbon (g kg <sup>-1</sup> )	165
Potassium (mg kg <sup>-1</sup> )	8452
Total Solids (%)	69.8
Volatile Compounds (%)	30.0
pH	8.6
Humidity (%)	27.2
Cation Exchange Capacity (mmol <sub>c</sub> kg <sup>-1</sup> )	314
C:N Ratio	15

<sup>(1)</sup> Except for humidity, results are expressed based on dry weight.

Liming of the total area was conducted by applying 1.2 t ha<sup>-1</sup> of dolomitic limestone (PRNT 95%) and was based on the soil base saturation of the experimental area. At 60 days after the previous turfgrass sod harvest, the single application fertilization was applied. The first application of the split application was also applied at that time with the second application occurring at 127 days after the first, when the soil cover rate (SCR) reached 50%. In the plots treated with urea, a dose of 300 kg N ha<sup>-1</sup> was given in a single application, corresponding to 670 kg ha<sup>-1</sup>, at 25 days after the beginning of the experiment.

Three methods were used to evaluate zoysia grass sod production: soil cover rate (SCR), green color intensity (GCI), and leaf nitrogen content analysis.

Soil cover rate (SCR) was assessed through a digital image. The images were taken parallel to the lawn surface with a 3.0-megapixel digital camera coupled to a lightbox, similar to that described in Peterson *et al.* (2011), which standardizes the lighting and the image area. Subsequently, images were analyzed in Sigma Scan software and the SCR percentage was obtained by counting green pixels.

Green color intensity (GCI) was obtained using the non-destructive absorbance method in a portable Chlorophyll Meter, Soil and Plant Analysis Development (SPAD) Model 502 (Minolta Co., Osaka, Japan). Leaves were collected from each plot, placed in plastic bags, and stored in a Styrofoam box with ice for transportation to the laboratory. Shortly after arrival at the laboratory, the leaves were hydrated and a reading taken for each leaf, with 30 leaves analyzed per plot, to obtain an average value per treatment. SCR and GCI were measured at 45, 93, 127, and 156 days after application (DAA) of sewage sludge compost.

For the analysis of leaf nitrogen content, grass was cut in the plots and the shavings were ground and sent to the Plant Nutrition Laboratory in the Soils and Environmental Resources Department/Unesp, following a modified methodology based on Malavolta *et al.* (1997). Analyses were performed at 93 and 156 DAA of sewage sludge compost.

Data were submitted to analysis of variance and regression methods. Nitrogen dose effects were compared using Tukey's test, with  $p = 0.05$ . Statistical analyses were performed using the software Minitab16.

### 3. RESULTS AND DISCUSSION

Soil cover rate (SCR) of zoysia grass showed significant interaction between dose and application at only 45 and 156 DAA of composted sludge ( $p < 0.05$ ) (Table 2). According to Godoy (2007), soil cover rate is the first indicator in the formation of turfgrass sod.

**Table 2.** Means and summary of analysis of variance of soil cover rate (SCR) (n=5).

Soil Cover Rate (%)								
Doses of SSC	45 DAA		93 DAA		127 DAA		156 DAA	
Mg ha <sup>-1</sup>	Application							
	1	2	1	2	1	2	1	2
0	18.5b	19.0a	27.9	35.6	56.6	62.8	60.9 Abc	49.7Bb
10	24.6b	20.0a	32.9	37.3	61.5	60.3	59.3bc	55.6b
20	27.2b	22.2a	30.9	29.3	65.1	62.8	75.0Aab	64.2Bab
30	31.8b	22.2a	30.1	26.6	66.9	58.7	82.4Aa	63.0Bab
40	48.7Aa	22.5Ba	39.6	31.1	66.7	62.4	90.0Aa	72.0Ba
Urea	18.3b		36.8		68.9		68.7c	
p								
Dose (D)	0.0001		0.547		0.841		0.0001	
Application (A)	0.0001		0.953		0.248		0.0001	
D x A	0.001		0.713		0.721		0.032	
C.V (%)	29.00		36.7		25.45		5.58	

Means followed by the same lowercase letters in the column and uppercase letters in the rows do not differ statistically based on a Tukey test.

1 – Single application; 2 – Split application.

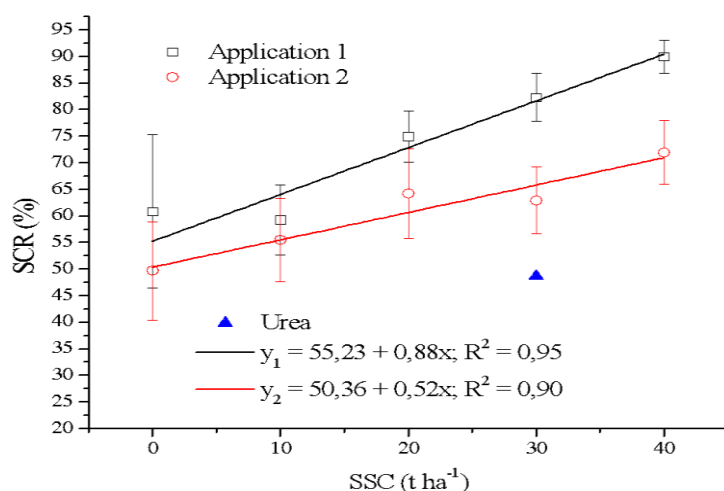
Splitting the composted sludge into two applications showed no advantage compared to the single application at all sampling times for SCR. An explanation for this effect arises from the fact that a greater mass of organic matter in the soil retains a greater volume of water, especially during periods without rain. Another factor that may have contributed to this result is the period required for decomposition of the second portion of the sludge compound applied in November. The amount of time may not have been sufficient to release all nutrients. According to the nutrient evaluation conducted by Backes *et al.* (2013), 67% of the N is released within a period of up to 120 days. Meanwhile, Godoy *et al.* (2007) note the need for basic fertilization for shoot development to begin.

The largest applied dose (40 Mg ha<sup>-1</sup>) provided a maximum coverage rate (SCR 100%) at 212 DAA. Backes *et al.* (2009), in their study to verify non-composted sewage sludge doses in zoysia grass sod production, found that a single application of 40 Mg ha<sup>-1</sup> produced the maximum coverage rate at 165 DAA. Meanwhile, in a different study, Backes *et al.* (2013) evaluated the effects of composted sewage sludge on the production of zoysiagrass and found that a dose of 46.8 Mg ha<sup>-1</sup> produced the maximum SCR only at 380 DAA. These results suggest that the addition of a carbon source during the sewage sludge composting process dilutes the nutrients in the sludge, thus requiring a higher dose to reach the maximum SCR.

Plots that received syntetic fertilization (SF) showed a SCR of approximately 21%, 12%, 10% and 29% lower in comparison to the highest dose of applied sludge. Backes *et al.* (2013), comparing a dose of 48 Mg ha<sup>-1</sup> of sludge with a control (no fertilization), showed a lower SCR by 61% and 65% at 45 and 130 DAA, respectively.

At 127 DAA, treatments with SF provided an SCR 2.2% greater than the highest dose of applied SSC, and at 156 DAA the highest SSC dose showed a 20% increase over IF (Figure 2). This result can be directly related to the effect of soil moisture, which favors the decomposition of organic matter and slows the release of nutrients with the application of the SSC in comparison to urea.





**Figure 2.** Soil Cover Rate (SCR) for zoysia grass as a function of the sewage sludge compost doses, urea, and methods of application, at 156 days after application (DAA) of sludge compost.

Green color intensity (GCI), represented by the SPAD value, is directly related to the concentration of chlorophyll in the leaves, representing a higher production of carbohydrates and quick rooting of the sod after planting (Christians, 1998). The doses of composted sewage sludge and the two methods of application significantly influenced the GCI at 45 and 93 days after application. At 127 DAA of composted sewage sludge, a significant effect was observed only for the applied doses (Table 3).

**Table 3.** Means and summary of analysis of variance of green color intensity (GCI) (n=5).

Green Color Intensity (SPAD)										
45 DAA			93 DAA			127 DAA			156 DAA	
Doses of SSC	Application									
	Mg ha <sup>-1</sup>	1	2	1	2	Mean	1	2	Mean	1
0	27.9 Ac	27.0 Aa	26.9	27.4	27.1 b	26.5	26.1	26.3 b	27.8	27.2
10	30.4 Abc	28.7 Aa	28.4	29.3	28.8 ab	27.6	25.9	26.7 ab	26.6	25.6
20	31.6 Abc	28.7 Aa	28.6	27.4	28.0 ab	27.8	26.9	27.3 ab	26.8	26.7
30	35.0 Aab	30.7 Aa	31.5	29.2	30.3 a	29.0	29.2	29.1 ab	27.7	27.1
40	37.0 Aa	30.5 Ba	32.4	28.8	30.6 a	31.7	26.9	29.3 a	29.5	28.6
Mean			29.5 <sup>a</sup>	28.4B		28.5	27.0			
Urea	27.6 Ac	-	28.8	-	28.8 Aab	26.4	-	26.4ab	25.5	-
p										
Dose (D)	0.0001		0.004		0.016		0.320			
Application (A)	0.0001		0.026		0.071		0.820			
D x A	0.007		0.221		0.119		0.914			
C.V (%)	7.02		7.85		8.37		11.23			

Means followed by the same lowercase letters in the column and uppercase letters in the rows do not differ statistically based on Tukey test.

1 – Single application; 2 – Split application.

At 45 DAA, GCI can be expressed as a linear model that increases with an increase in the applied sludge dose: ( $y_1 = 27.83 + 0.23x$ ,  $r^2 = 0.99$ ) and ( $y_2 = 27.14 + 0.09x$ ,  $r^2 = 0.90$ ), split application and single application, respectively.

We also found that GCI at 45 days after application was greater in relation to the other evaluated time periods, due to a greater release of N until that date, corroborating the results found by Backes *et al.* (2010). At 45 DAA, we observed green color indices ranging from 27.9 to 37 SPAD units, which supports the concept that beginning from a N deficiency situation there is a linear response of GCI with increasing doses (Fig. 2), related to increasing chlorophyll content of the grass (Carvalho *et al.*, 2003). Unlike the results observed for SCR, we found statistical differences between the treatments for doses and application method, with the highest values (35 and 37 SPAD) obtained with a single application of SSC for doses of 30 and 40 Mg ha<sup>-1</sup>, as shown in Table 3. As the GCI is correlated with levels of N, we can infer that with an applied dose of 30 Mg ha<sup>-1</sup>, the zoysia grass reached the maximum value of N, and this may indicate an optimal dose for this parameter.

The assessment at 156 DAA did not present statistically different results; however, it was possible to observe differences in soil cover (SCR, presented in Table 2) and, consequently, plant mass. This fact could have generated a uniformity in GCI results, since treatments with a greater dose of composted sludge showed increased plant growth. As such, N was diluted in the aerial part of the plant, which caused a decrease in concentration in comparison with the control or lower doses of SSC. Beard (1973) observed the effect of dilution on chlorophyll concentration when very high doses of N were used, leading to a reduced GCI.

GCI varied throughout the experiment, ranging from 27 to 37 SPAD. Our findings indicate that zoysia grass that received high doses of N achieved a GCI greater than 37 SPAD units at 90, 192, and 296 days after cutting (DAC). However, when no N was applied, the GCI ranged from 22.9 to 28.9 at 124, 192, and 296 DAC.

Our data suggest a significant interaction between dose and application for mean N leaf concentration at 93 and 156 days after application (Table 4).

**Table 4.** Means and summary of analysis of variance of foliar leaf N concentration (n=5).

Foliar leaf N concentration (g kg <sup>-1</sup> )					
		93 DAA		156 DAA	
Doses of SSC		Application			
Mg ha <sup>-1</sup>		1	2	1	2
0		10.39c	10.85	13.89	12.93
10		12.19bc	11.86	12.64	10.22
20		13.64bc	11.52	14.74	12.74
30		14.71Ab	11.21 B	12.74	10.13
40		18.95Aa	12.81 B	15.03	11.72
Urea		10.21c	-	11.68	-
p					
Dose (D)		0.001		0.505	
Application (A)		0.001		0.058	
D x A		0.001		0.937	
C.V (%)		12.64		29.44	

Means followed by the same lowercase letters in the column and uppercase letters in the rows do not differ statistically based on Tukey test.

1 – Single application; 2 – Split application.



We observed a linear increase in the N concentration in leaf blades ( $y = 9.59 + 0.23x$ ,  $R^2 = 0.97$ ), reaching a maximum value of  $18.95 \text{ g kg}^{-1}$  at 93 DAA with a single dose treatment of  $40 \text{ Mg ha}^{-1}$  composted sewage sludge (Table 4). Experiments performed in the field and in greenhouses, with the application of *in natura* and composted sewage sludge, also showed a linear increase in nitrogen concentration in leaf blades (Backes *et al.*, 2010; Tester, 1989).

The maximum value found for N is slightly below the ideal range of 20 to  $24 \text{ g kg}^{-1}$ , as suggested by Mills and Jones (1996). Backes *et al.* (2010), studying the effects of *in natura* sewage sludge, found a N concentration of  $28 \text{ g kg}^{-1}$  at 105 DAA.

At 156 DAA, with the dose of  $40 \text{ Mg ha}^{-1}$ , we found a N concentration in the leaf blade of  $15.03 \text{ g kg}^{-1}$ , which provided the highest SCR of 90%. At 105 DAA, Backes *et al.* (2009) found that a foliar leaf N concentration of  $17 \text{ g kg}^{-1}$  provided more than 95% of SCR and at 165 DAA the concentration range was from 19 to  $22 \text{ g kg}^{-1}$ .

From the results, we can infer that, due to the dilution effect, there is a tendency toward a decrease in the nutrient concentration in the leaf throughout the cycle, where a redistribution of N occurs with an increase in the total plant mass. The management of the lawn including the trimming and removal of cuttings, and the consequent removal of nutrients, also explains the reduction in concentration of N at 156 DAA. For this study, a dose of  $30 \text{ Mg ha}^{-1}$  can be considered optimum, since the increase in SPAD value of approximately 5% does not justify increasing the dose to  $40 \text{ Mg ha}^{-1}$ , considering the costs of production.

## 4. CONCLUSIONS

A  $30 \text{ Mg ha}^{-1}$  dose of sewage sludge compost is the most suitable for sod production.

A divided application of sewage sludge compost is not recommended.

Sewage sludge compost used in the production of zoysia grass had beneficial effects and the use of SSC in zoysia grass sod production can substitute urea fertilization.

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