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Research Paper

Is organic fertilizer application a viable alternative to synthetic fertilizer for Piatã grass?

¿Son los fertilizantes orgánicos una alternativa viable a fertilizantes sintéticos para el pasto Piatã?

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Abstract

Organic fertilizer in many cases can replace mineral fertilizers and in consequence reduce production costs and improve soil quality. Thus, the aim of this work was to evaluate productive, morphogenic and structural characteristics of Piatã grass (*Urochloa brizantha*) fertilized with urea, organic compost and biofertilizer throughout a year. The trial design was a block split-plot in time (seasons) design with 4 treatments (fertilizing with urea, organic compost, biofertilizer and Control) and 6 repetitions. The evaluated parameters were: dry matter production (DMP), leaf elongation rate (LER), leaf appearance rate (LAR), phyllochron (PHYL), leaf lifespan (LLS), pseudostem elongation rate (SER), final leaf length (FLL), number of live leaves (NLL) and number of tillers (NT). The highest LAR values were observed during summer and spring for the treatment with urea, which also produced the highest LER values. No difference was found in SER among the fertilizer treatments but all fertilized treatments were superior to Control. NT and DMP values were highest ($P<0.05$) in the treatment with urea, followed by biofertilizer, organic compost and Control. In conclusion, while the use of urea provided greatest forage production, applying biofertilizer gave superior yields to organic compost. Other benefits of organic fertilizers should be assessed as well as combinations of organic and inorganic fertilizers.

Keywords: Biofertilizer, nitrogen, organic compost, season, urea, *Urochloa brizantha*.

Resumen

La fertilización orgánica, en muchos casos, puede reemplazar a los fertilizantes minerales y, en consecuencia, reducir los costos de producción y mejorar la calidad del suelo. Así, el objetivo de este trabajo fue evaluar las características productivas, morfológicas y estructurales del pasto Piatã (*Urochloa brizantha*) fertilizado con urea, compuesto orgánico y biofertilizante durante un año. Para eso, se utilizó un diseño de bloques con parcelas divididas en el tiempo (estaciones), compuesto por cuatro tratamientos (fertilización con urea, compuesto orgánico, biofertilizante y control) y seis repeticiones. Los parámetros evaluados fueron: producción de materia seca (DMP), tasa de elongación de hojas (LER), tasa de aparición de hojas (LAR), filocrón (PHYL), vida útil de las hojas (LLS), tasa de elongación de pseudotallo (SER), longitud final de la hoja (FLL), número de hojas vivas (NLL) y número de macollas (NT). Los valores de LAR más altos se observaron durante el verano y la primavera para el tratamiento con urea, que también producjo los valores más altos de LER. No se encontró diferencia en el SER entre los fertilizantes probados, sin embargo, hubo una diferencia entre estos tratamientos y el control. Los valores de NT y DMP fueron mayores en el tratamiento con urea, seguido de biofertilizante, compuesto

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orgánico y control. Se puede concluir que el uso de urea brindó mayor rendimiento forrajero, sin embargo, la fertilización orgánica con biofertilizante resultó ser más ventajosa en comparación con el compuesto orgánico.

Palabras clave: Biofertilizante, compost orgánico, estaciones del año, nitrógeno, urea, *Urochloa brizantha*.

Introduction

The use of synthetic fertilizer is the most common way to restore soil nutrients; however, its use is becoming impractical due to high prices on the international market. According to data published by ANDA (2019), 36 million tonnes of fertilizer were applied in Brazil in 2019, and approximately 80% of this material was imported. It is possible that use of an alternative form of nutrients, e.g. organic fertilizer made from organic waste, could greatly reduce agricultural fertilizer costs in the country.

The utilization of organic fertilizer may be a viable alternative for fertilizing tropical pastures (Orrico Jr. et al. 2012). Organic wastes are cheaper than conventional inorganic fertilizers and contain additional nutrients important for forage growth. In the literature, there are several studies that prove the efficiency of using organic fertilizers on pastures (Orrico Jr. et al. 2013; Ryals et al. 2016; Grave et al. 2018; Orrico Jr. et al. 2018). However, there is a very wide variety of organic wastes with different chemical compositions, which may lead to a great variety of responses. Among the main waste treatment systems are composting (aerobic process producing solid fertilizer) and biodigestion (anaerobic process producing liquid fertilizer), which result in the production of organic compost and biofertilizer, respectively. Even when the same raw material (poultry litter for example) is used, the final chemical composition and its value as fertilizer may be markedly different between these two types of fertilizer, which could result in distinctly different responses (Bowden et al. 2007).

Therefore, this research aimed to determine if organic compost and biofertilizer produced different responses in growth and productivity of the pasture grass Piatã (*Urochloa brizantha*), and to assess differences in responses produced between these organic fertilizers and urea when applied to the grass.

Material and Methods

The trial was carried out in a greenhouse at the experimental area of Embrapa Agropecuária Oeste, Dourados, Mato Grosso do Sul, Brazil (22°16’30” S, 54°49’00” W). The climate in the region according to the Köppen classification is type Cwa (humid mesothermal, with hot summers and dry winters). The meteorological data recorded during the experiment are presented in Figure 1.

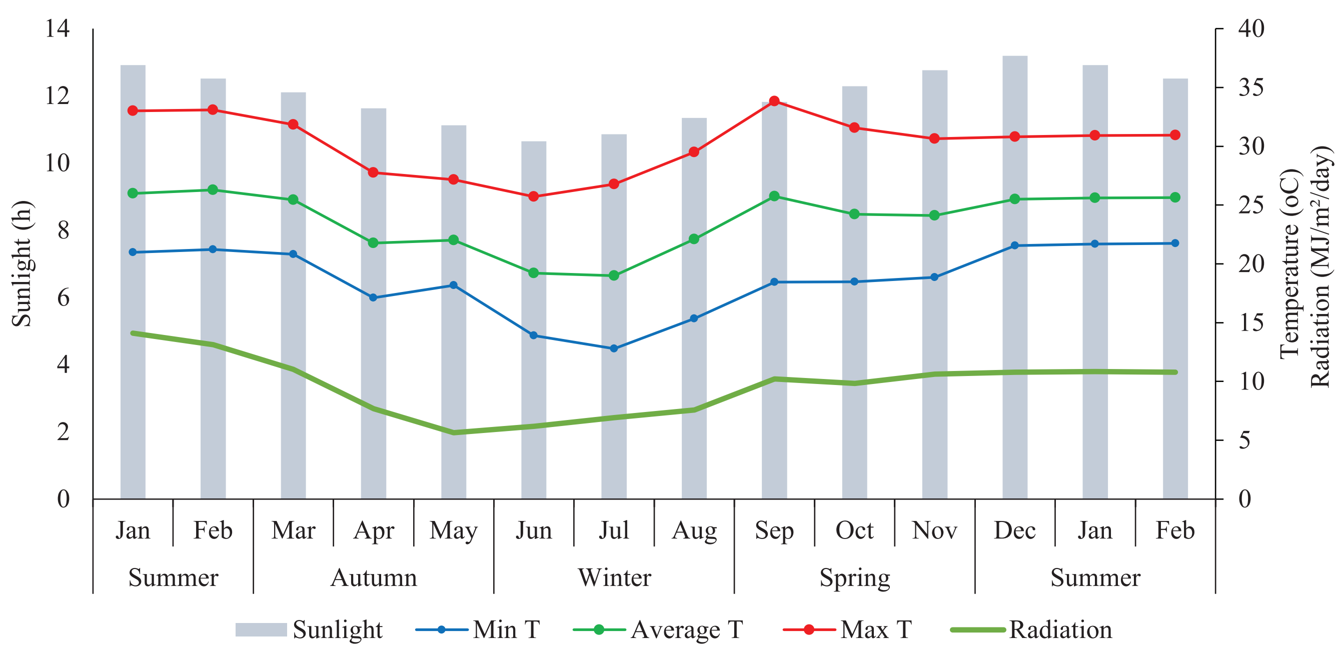

Figure 1. Average (average T), maximum (Max T) and minimum (Min T) air temperatures, hours of sunlight and radiation measured during the experimental period (2017–2018) at Dourados-MS, Brazil.

The soil used was an Oxisol of clay texture with the following characteristics: sand, 12.8%; silt, 10.7%; clay, 76.5%; pH in $CaCl_2$, 4.78; P, 5.14 mg/dm^3; K, 1.00 cmolc/dm^3; Ca^{2+}, 2.86 cmolc/dm^3; Mg^{2+}, 1.29 cmolc/dm^3; Al^{3+}, 0.15 cmolc/dm^3; H+Al, 6.08 cmolc/dm^3; cation-exchange capacity (CEC), 11.22 cmolc/dm^3; OM, 27.24 g/kg; and base saturation, 45.85%.

A block split-plot in time (seasons) design with 4 treatments, i.e. Control (= no fertilizer) and fertilization with urea, organic compost and biofertilizer, and 6 replicates, was used giving a total of 24 experimental units (40 L pots). All fertilized pots received 400 kg N/ha/year (0.8 g N/pot), applied in ten 40 kg N/ha applications. The concentrations of N, P, K, Mg, Ca and Na were 2.13, 1.77, 2.6, 0.41, 0.86 and 0.71 g/100 g in compost and 0.23, 0.19, 0.31, 0.05, 0.09 and 0.071 g/100 mL in biofertilizer, respectively.

Soil moisture in the pots was maintained at around 70% of field capacity throughout using an irrigation system. On 6 December 2016, 30 seeds of Piatã grass (*Urochloa brizantha*; syn. *Brachiaria brizantha*) were sown in each pot. Seven days after emergence, seedlings were thinned to retain the most vigorous 9 plants in each pot. A standardization cut was made 50 days after sowing (25 January 2017) at 20 cm from the soil surface (beginning of the experimental period). Subsequently, evaluation harvests were performed every 35 days at 20 cm from the soil. After each harvest, the next application of fertilizer was applied and a new data collection cycle began. Pots were irrigated when fertilizer was applied, to reduce nitrogen loss by urea volatilization. Ten harvests were made between 1 March 2017 and February 2018.

The total weight of green forage contained in the pots above a height of 20 cm from the soil was recorded at each harvest. The material collected was taken to the laboratory and placed in a forced-air oven at 65 °C for at least 72 h to determine the dry matter concentration according to the methodology described by AOAC (2005).

In order to assess forage morphogenic and structural characteristics, 3 tillers per pot were tagged with colored string after the standardization cut. The leaves and living and senescent parts were measured every 3 days with a rule and the data were used to calculate the following morphogenic and structural characteristics: (1) leaf appearance rate (LAR, leaves/tiller/day) - the number of leaves that appeared divided by the number of days of cycle evaluation; (2) phyllochron (PHYL, days) - the interval between the appearance of 2 consecutive leaves on a tiller, the opposite of LAR; (3) leaf elongation rate (LER, cm/tiller/day) - the difference between the final and initial lengths of leaf blades divided by the number of days of the evaluation period; (4) pseudostem elongation rate (SER, cm/tiller/day) - the difference between initial and final stem lengths divided by the number of days of evaluation; (5) leaf lifespan (LLS) - the number of live leaves multiplied by the phyllochron; (6) final leaf length (FLL, cm/tiller) - the mean leaf blade length of all expanded leaves present on a tiller; (7) number of live leaves (NLL) - the total number of green leaves on each tiller; and (8) number of tillers (NT) - the total number of green tillers in each pot.

The parameters were submitted to analysis of variance using the split-plot in time scheme (using the PROC MIXED procedure) to assess the effect of the main treatments (fertilizer types), secondary treatments (seasons) and their interaction (fertilizer type × season). The means of the treatments were compared by Tukey's test at 5% probability. The statistical analysis was performed through the software SAS 6.1.

Results

PHYL, LAR, LLS and NLL showed interactions ($P<0.01$) between season and type of fertilizer applied (Figure 2). LAR on treatments fertilized with urea during summer and spring was greater ($P<0.05$) than those for the remaining treatments. However, during autumn and winter differences in LAR between fertilized treatments were small and LAR on all fertilized treatments exceeded ($P<0.05$) those of Control. Overall highest LAR values occurred in summer and the lowest in winter ($P<0.05$). PHYL values followed the inverse behavior of LAR, with highest values being recorded in winter, the absolute highest value (29.9 days) for Control in winter and the lowest values for all treatments in summer.

Control had longer ($P<0.05$) LLS than fertilized treatments in autumn and winter but there were no differences between treatments in summer and spring ($P>0.05$). The highest LLS value was obtained for the Control during winter (176 days) with about 40 days in summer and spring. NLL values varied from 5 to 6.5 leaves/tiller between treatments tested, with no consistent difference between treatments.

There were no significant interactions between season and fertilizer type for other parameters, so main effect responses only are shown in Table 1. LER values were significantly affected by fertilizer type, being highest for the urea treatment (3.99 cm/d) and lowest for Control (2.49 cm/d) with compost and biofertilizer intermediate (mean 3.5 cm/d) ($P<0.01$). Pseudostem elongation rate

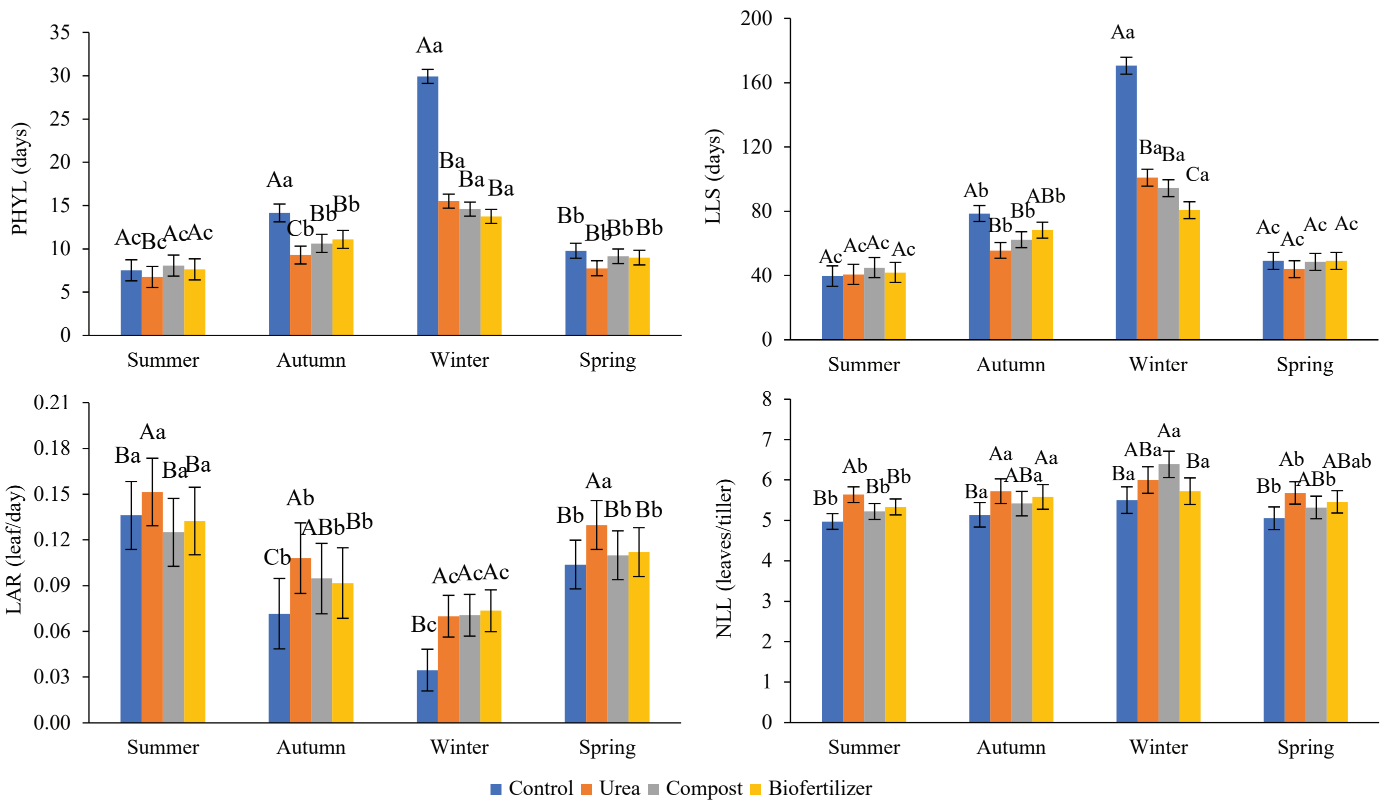

Figure 2. Effects of fertilizer type and season on phyllochron (PHYL), leaf appearance rate (LAR), leaf lifespan (LLS) and number of live leaves (NLL) of Piatã grass.
PHYL: effects of type of fertilizer (P<0.01), season (P<0.01) and interaction between type of fertilizer and season (P<0.01) (s.e.m. = 0.634).
LAR: effects of type of fertilizer (P<0.01), season (P<0.01) and interaction between type of fertilizer and season (P<0.01) (s.e.m. = 0.003).
LLS: effects of type of fertilizer (P<0.01), season (P<0.01) and interaction between type of fertilizer and season (P<0.01) (s.e.m. = 3.548).
NLL: effects of type of fertilizer (P<0.01), season (P<0.01) and interaction between type of fertilizer and season (P=0.03) (s.e.m. = 0.049).
Means for season with different lower-case letters differ by Tukey's test (P<0.05); and means for fertilizer type with different upper-case letters differ by Tukey's test (P<0.05).

was greater for all fertilizer treatments than for Control (P<0.01), resulting in final leaf length following the same pattern (P<0.01). Parameters with the greatest fertilizer effects were number of tillers/pot and DM yield/pot. The urea treatment produced the greatest number of tillers/pot followed by biofertilizer, compost and Control with significant differences between all treatments. This resulted in significant differences in DM yields/pot for all treatments, with the highest yield for urea (8.47 g DM/pot) and the lowest for Control (3.88 g DM/pot).

Both LER and SER were strongly affected by season with the following order: summer > spring > autumn > winter (Table 1; P<0.01). Leaf growth in winter was less than half of that in summer, while pseudostem growth virtually ceased in winter. Final leaf length in summer and spring exceeded those in autumn and winter (P<0.01). However, number of tillers per pot was greatest in summer with no difference between other seasons (P<0.01). As might be expected for tropical grasses, DM production was greatest in summer (9.16 g DM/pot) and lowest in autumn and winter (mean 4.59g DM/pot), with spring intermediate (mean 6.40 g DM/pot).

Table 1. Effects of fertilizer type and season on productive, morphogenic and structural characteristics of Piatã grass.

Parameter	Fertilizer				Season				s.e.m.	P value		
	Control	Urea	Compost	Biofertilizer	Summer	Autumn	Winter	Spring		F	S	F*S
LER (cm/d)	2.49C	3.99A	3.43B	3.56B	4.81a	2.95c	1.84d	3.88b	0.135	<0.01	<0.01	ns
SR (cm/d)	0.03A	0.03A	0.03A	0.02A	0.01a	0.02a	0.02a	0.01a	0.004	ns	ns	ns
SER (cm/d)	0.44B	0.58A	0.54A	0.58A	0.78a	0.61c	0.05d	0.70b	0.031	<0.01	<0.01	ns
FLL (cm)	14.6B	19.0A	17.4A	18.5A	18.2a	17.2b	16.3b	18.2a	0.288	<0.01	<0.01	ns
NT (no./pot)	75D	122A	89C	101B	117a	94b	95b	96b	1.859	<0.01	<0.01	ns
DMP (g DM/pot)	3.88D	8.47A	5.88C	6.50B	9.16a	4.47c	4.70c	6.40b	0.561	<0.01	<0.01	ns

LER = leaf elongation rate; SR = senescence rate; SER = pseudostem elongation rate; FLL = final leaf length; NT = number of tillers; DMP = dry matter production. Means for season with different lower-case letters differ by Tukey's test (P<0.05) and means for fertilizer type with different upper-case letters differ by Tukey's test (P<0.05).

Discussion

This glass-house study has provided valuable information on the variation in growth responses in Piatã grass to inorganic and organic fertilizers throughout the year. While urea produced a 118% increase in DM yield over the unfertilized Control, responses with biofertilizer were only 67% and with compost were 52%. These differences are probably a function of differences in the ready availability of the N in the various fertilizers. The published literature suggests there is a strong positive correlation between availability of N in the fertilizer applied and growth responses in tropical forages (Al-Solaimani et al. 2017; McRoberts et al. 2018). With synthetic fertilizers like urea, a high proportion of the N is readily available to plants and can be rapidly absorbed to produce rapid growth responses (Bowden et al. 2007). On the other hand, the availability of N in the organic fertilizers depends on a range of factors, including C:N ratio in the fertilizer, origin of the material and the treatment to which the waste has been subjected (Gutser et al. 2005). When organic residues are submitted to anaerobic biodigestion, NH^{4+}-N concentration in the effluents increases, which leads to a higher proportion of the N being available for plants (Gutser et al. 2005). Organic compost presents significant levels of N in organic form, which becomes more slowly available in the soil. This would help to explain why organic compost had the lowest values of dry matter production between the types of fertilizer tested.

Orrico Jr. et al. (2018) required a 4.8-fold higher dose of organic compost to reach the same forage production obtained by Orrico Jr. et al. (2013) with the use of biofertilizer. Although this comparison refers to separate studies, these were both pot studies performed by the same authors under very similar environmental conditions, i.e. type of forage, soil type and season.

The morphogenic and structural characteristics of Piatã grass that were measured supported the growth responses obtained, with leaf appearance rate (LAR) being greater for urea treatments than for other treatments in spring and summer in particular and LER and SER on all fertilized treatments exceeding those of Control. The superiority of urea over compost and biofertilizer in producing rapid growth responses was reflected in the higher LAR values for urea combined with the greater values for LER. Higher values of LAR and LER result, in most cases, in forages with a high proportion of leaves. Fertilizers that promote a high proportion of leaves also produce forage with high levels of crude protein. Mihret et al. (2018) also observed higher values of LAR, LER and CP in grasses fertilized with synthetic fertilizers (NPK) when compared with organic fertilizer. Unfortunately, we did not measure the CP concentration in the forage in this study.

Higher numbers of tillers per pot with urea were an important component of the superior responses produced with this fertilizer. According to Fagundes et al. (2006), ready availability of N leads to more rapid formation of axillary buds (due to greater LAR values), which, consequently, contributes to the emergence of new tillers. This greater density of young tillers in the pasture results in the improvement of forage productivity (Caminha et al. 2010).

Another variable that deserves to be highlighted in this work is the marked seasonality of production of forage even under controlled conditions in a pot trial. According to Araujo et al. (2018), one of the main characteristics of tropical forages is seasonality of production, with growth being greatest during summer and spring seasons. Although this study was carried out in pots, the forage was exposed to the same variations of regional photoperiod and temperatures as would be the case in a field study. Of the total annual production obtained (24.73 g DM/pot or equivalent to 12,376 kg DM/ha), proportions produced in different seasons were:

26, 37, 18 and 19% for spring, summer, autumn and winter, respectively. This highlights the important effects of both temperature and hours of daylight on growth of tropical pastures, in this case Piatã grass, since the study was conducted under conditions where soil moisture levels were maintained at 70% field capacity throughout. When seasonality of rainfall is taken into account, one might question whether or not N application in autumn and winter in the absence of irrigation is warranted and this aspect should be investigated in field studies.

These results are important because, on many farms, fertilizing of pastures with organic fertilizer is frequently practiced during all months of the year. Waste is produced daily and converted to compost or biofertilizer and farmers do not store the waste for lengthy periods (mainly biofertilizers, that are very diluted). Nitrogen applied during seasons when the grass cannot absorb it can lead to an excess of N in the soil, with possible contamination of groundwater (Blum et al. 2013); further investigations of this system seem warranted.

Conclusions

Application of synthetic fertilizer (urea) resulted in greater forage production than application of organic fertilizers. However, there are other benefits from applying organic fertilizer, such as increase in soil organic matter, improvement in soil structure, etc. While the fertilizer N in urea was readily available for plants, the slow release of N from the biofertilizers does not necessarily mean that the remaining N is lost from the system. This N could become available for plant use subsequently. Since waste is a by-product of agricultural systems and must be disposed of in an environmentally safe manner, application to fields to reduce the levels of inorganic fertilizer to be applied is a beneficial practice. These aspects warrant further investigation.

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(Note of the editors: All hyperlinks were verified 28 July 2021).

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