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Sugarcane Production Based on Mineral and Organic Nitrogen Fertilizers for Ruminant Feeding

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Abstract

Sugarcane may be a potential feed source for ruminants in tropical and subtropical areas. An important factor that can influence the nutritional quality of sugarcane for animal feeding is nitrogen fertilization management, however, studies on this subject are still scarce. In this context, the objective of this study was to evaluate the effect of nitrogen sources on the quality and productivity of sugarcane as a forage resource. The variety of sugarcane used was RB92579, with application of nitrogen (N) sources (urea, poultry litter, swine manure) and control (without N application). Stalk productivity and dry matter, crude protein, neutral detergent fiber, acid detergent fiber, lignin, Brix, NDF / Brix ratio, and in situ digestibility were analyzed during incubation periods of 6, 24, and 72 hours. At the end of the study, it was found that the N sources did not interfere with sugarcane stalk productivity ($P > 0.05$), with an average productivity of 102 t ha^{-1}. The N treatments did not influence ($P > 0.05$) in the nutritional quality of sugarcane, when evaluating the contents of dry matter, crude protein, neutral detergent fiber, acid detergent fiber, lignin, Brix and NDF / Brix ratio. The dry matter degradation had an effect ($P < 0.05$) for the different N sources and incubation times, where poultry litter and swine manure treatments showed higher values for degradation at 72 hours of incubation. The different N organic sources did not interfere in the chemical composition and productivity of the sugarcane culture, however it presented better results in the in situ degradability of the dry matter. This, it can be recommended that mineral nitrogen fertilizers can be replaced by organic fertilizers.

Keywords: saccharum officinarum, poultry litter, swine manure, urea

1. Introduction

Livestock farming has a high cost and depends on the sources used in the animal feeding. Thus, the use of alternative sources that can increase profitability in the activity is needed. In this context, the sugarcane is a crop with great forage potential, once it presents high production of green mass, maintenance of nutritional quality during the dry period and the need to renew the cane field only from the fourth year onwards of culture production. However, to improve the use of sugarcane as a bulky food, it is necessary to correct the main nutritional limitations of the crop, highlighting its low protein content, combined with low fiber digestibility. For this purpose, an option is to supplement sugarcane with a non-protein nitrogen source, such as urea, thus compensating the deficiency in crude protein content (Gunun et al., 2016).

Sugarcane is capable to support different animal categories; but to obtain high productivity it must be managed correctly, supplied of all necessary nutrients for a desirable development. For a suitable sugarcane yield, the first nutrient to be corrected is nitrogen (N), since it is an essential element for the culture to express its high productive potential (Costa et al., 2016). However, nitrogen is the most complex nutrient, due to its multiple chemical and biological reactions in the soil, which are directly influenced by soil type and climate conditions, what makes it difficult to manage and recommend this nutrient (Atucha, Merwin, & Brown, 2011).

Due to its complex reactions, the N applied to the soil with the use of inorganic fertilizer has a great potential to be lost in several ways, and it is associated with soil, water and air pollution. Furthermore, inorganic N fertilizers represents a high cost in the productive chain, and their use may not be suitable for small farms (Jagwe, Chelimo, Karungi, Komakech, & Lederer, 2020). Therefore, it is essential to search for nitrogen sources that present satisfactory results in crop production, with lower N losses, and preferably with lower costs. The use of organic amendments such as cattle manure is an alternative to these detrimental effects of inorganic fertilizers because of its wide-spread availability, its additional value for soil carbon sequestration, and its capacity for storing and releasing nutrients over a longer time period.

In this context, Chew, Chia, Yen, Nomanbhay, and Show (2019) stated that it is economically viable and environmentally sustainable to use animal waste as nitrogenous organic fertilizers, since they provide an increase in crop yield, in addition to be an alternative for the use of these residues, with a view to reducing environmental impacts. Thus, the objective of this study was to evaluate the effect N mineral and organic fertilizers on the quality and productivity of sugarcane as a forage resource.

2. Introduction

2.1 Description of the Experimental Area

The study was carried out in an experimental area of the Federal University of Maranhão, Center for Agricultural and Environmental Sciences, in the municipality of Chapadinha, located at 3°44 '26' 'latitude and 43°21' 33 " longitude. The region's climate corresponds in the Koppen classification to the Aw type, characterized by rain in the summer time, and drought in the winter. The average temperature during the experimental period was 27.4ºC, and the accumulation of precipitation was 1,599 mm. Temperature and precipitation data were obtained by the National Institute of Meteorology - INMET (Figure 1).

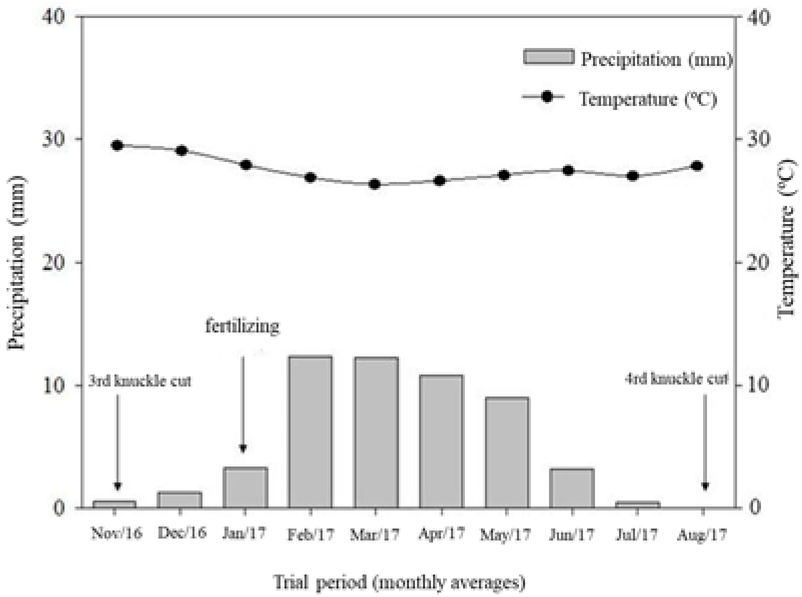

Figure 1. Monthly temperature and precipitation avarege during the experimental period in the municipality of Chapadinha-MA

The soil was classified as Yellow Latosol (EMBRAPA Soil Classification Manual, 2013), and presented the following characteristics: pH = 4.8 (in water); Ca = 0.81; Mg = 1.54; Na = 0.01; K = 0.01; Al = 0.48; H + Al = 4.83 (all in $cmol_c$ dm^3, except pH), P = 0.54 mg kg^{-1}, and OM = 3.9%.

The current experiment started with the application of nitrogen sources, in November 2016, 40 days after cutting the previous crop cycle. Nitrogen sources were urea (URE), poultry litter (PL) and swine manure (SM), and all of them were applied at a dose of 100 kg N ha^{-1}. There was also a control treatment (without fertilizer application). Potassium was applied as KCl (potassium chloride) at a dose of 120 kg K_2O ha^{-1} in all plots. The variety of sugarcane used in the study to assess nutritional value and yield after fertilization was the RB92579, in the fourth sock, which was harvested as cane plant in August 2017, and did not receive any type of pesticide to control weeds, pests or diseases, since it was not needed.

For the chemical and productivity analyzes, the experimental design was completely randomized. The treatments consisted of nitrogen mineral source (urea); organic sources (PL and SM), and control (without application of fertilizers), with four replications, totaling 16 experimental plots. Before application in the field, organic fertilizers undergone chemical analysis to determine the N content (Table 1).

Table 1. Chemical analysis of dry matter (DM), organic matter (OM), nitrogen (N), phosphorus (P) and potassium (K) contents of the organic fertilizers used in the experiment

Organic fertilizers	DM	OM	N	P	K
	--------- % ---------		--------------- $g\ kg^{-1}$ ---------------		
Swine manure	87.90	49.22	104.30	15.83	19.90
Poultry litter	2.79	72.92	16.80	6.64	7.46

As for the potential degradability of dry matter, the design was in randomized blocks, where the blocks were the incubation periods, and the plots were the treatments mentioned above.

The stalk productivity analysis was carried out in an area of 3 m^2 in each plot. After assessing fresh weight, three plants were collected from each plot, randomly. The stem was separated in each plant, being identified and pre-dried in a forced air circulation oven at 60°C, for 72 hours or until they reached constant weight, being subsequently grounded in a Willey mill to 1.0 mm particles to determination of dry matter (DM) content and, based on DM, crude protein (CP), according to AOAC procedures (2010); neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (LIG), according to Van Soest (1994).

The Brix content of the sugarcane was measured with a field refractometer, where three plants were taken at random, and samples of the stem juice were collected. After these determinations, the NDF / Brix ratio, proposed by Rodrigues, Primavesi, and Esteves (1997), taking into account the fiber content in relation to the content of soluble solids in sugar cane.

Ruminal degradation was obtained by using a 390 kg Girolando cow, rumen fistulated, according to the methodology of Tomich and Sampaio (2004). It was fed with fresh cane, corn and soybean meal. The samples were ground in a 5 mm sieve, and placed in TNT bags, weight 100 (100g / m2) in the proportion of 15 to 20 mg of sample per cm^2 of bag area (Nocek, 1988).

The bags were inserted into a larger, 20 x 30 cm polyester mesh bag with a cord for closing the mouth. The incubation periods adopted were 6, 24 and 72 hours (Sampaio, 1988), The bags were inserted in decreasing order of time for removal of all at the same time from the rumen, and immersion in ice water, in order to interrupt the fermentation process. The bags were washed under running water at the same time. These were then pre-dried in a forced air oven at 55 ° C for 72 hours for subsequent analysis of DM and for later determination of the potential degradability of DM (Ørskov & McDonald, 1979).

The stalk productivity data, DM, CP, NDF, ADF, LIG, Brix and NDF / Brix ratio showed normality by the Shapiro Wilk test and homoscedasticity by the Cochran test. Thus, they were subjected to analysis of variance (ANOVA) and comparison of means by the Tukey test, at 5% probability. For potential DM degradation, the Tukey test was applied with a significance of 5%.

3. Results and Discussion

There was no significant difference (P> 0.05) between the nitrogen sources evaluated for stem productivity in the RB92579 variety, which presented an average productivity of 102.1 t ha^{-1}, as shown in Figure 2. Anjos, Andrade, Garcia, Fiqueiredo, and Carvalho (2007) found similar results when working with swine manure, poultry litter and mineral fertilizer as nitrogen sources, in the sugarcane stalk yield, where they did not obtain a significant effect of the treatments.

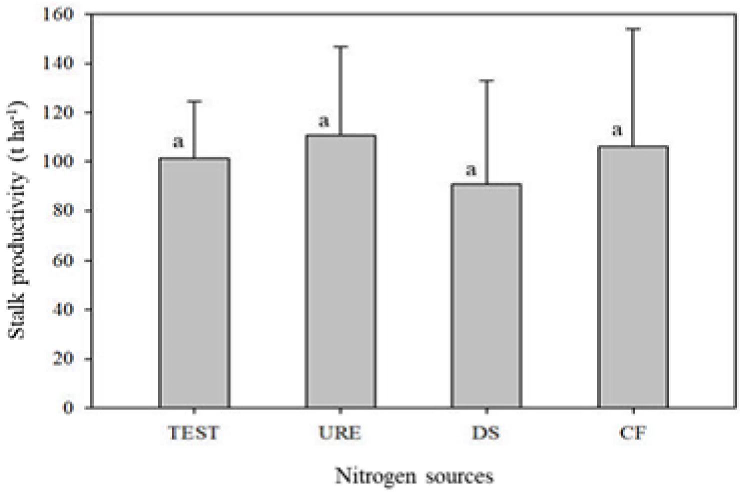

Figure 2. Sugarcane stalk productivity (t ha^{-1}) as a function of N sources in the RB92579 variety in the 4th cycle

Treatment means followed by equal letters do not differ by Tukey's test (P> 0.05). Coefficient of variation (%): 35.02%

Costa et al. (2017) obtained average productivity of stalks for this same variety of 128.8 t ha^{-1} in the third cycle, they commented that the RB92579 responded positively to nitrogen fertilization. This information is confirmed by the fact that these values were higher than the national average of 72.1 t ha^{-1} (CONAB, 2018).

Leite, Cunha Neto, and Resende (2009) obtained values similar to those found in the present study, which found average values of sugar cane productivity of 105.8 t ha^{-1}, in soil fertilized with swine manure as a nitrogen source using the same dose.

These results are favorable, since the crop yield with the application of organic sources was equivalent to the treatment with mineral fertilizer, and these results can be explained due to the increase in organic matter (OM) from organic fertilizers, which provide improvements in physical, chemical and biological quality of the soil, increasing the rate of infiltration and water retention, thus providing better conditions for the crop, and favoring the ability to maintain productivity along the cycles.

3.1 Chemical-Nutritional Analysis

Fertilization with different sources of N in the RB92579 variety did not influence (P> 0.05) in any of the chemical-nutritional variables analyzed (Table 2). These results are possibly because it was the first year of evaluation. However, they are within the range found in the literature for this variety.

Table 2. Values of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (LIG), soluble abrasives (Brix) and variety NDF / Brix ratio RB92579 in the 4th sugarcane cycle as a function of nitrogen sources

Sources of N	DM	CP	NDF	ADF	LIG	Brix	RATIO NDF/Brix
	--------	--------	%	--------	--------		
CON	31.07[a]	3.62[a]	41.16[a]	40.96[a]	6.19[a]	21.35[a]	1.98[a]
URE	30.05[a]	3.57[a]	41.30[a]	39.69[a]	6.50[a]	20.40[a]	2.06[a]
SM	30.26[a]	4.39[a]	45.04[a]	40.85[a]	6.34[a]	21.70[a]	2.22[a]
PL	30.63[a]	3.98[a]	44.00[a]	40.14[a]	6.17[a]	21.10[a]	2.13[a]
[1]CV (%)	6.69	13.55	6.92	951	7.37	9.34	14.73

Means followed by equal letters do not differ by Tukey's test (P> 0.05). [1]CV = Coefficient of variation.

Similar dry matter results were found by Costa et al. (2011). They obtained 30.4% of dry matter also in the fourth punch, whereas Cruz et al. (2009) found an average of 30.5%. The results were superior to those found by Thiago (2008), which on average was 23.6%.

The main reason to use sugarcane as an animal feed is its high mass production per unit area (Siqueira, Resende, Reis, Roman & Bernardes, 2008). An important parameter to be considered when choosing cultivars for animal feed, is the production of digestible dry matter per hectare, as this parameter considers both quantitative and qualitative aspects.

Crude protein values ranged from 3.57 to 4.39% and showed no statistical difference (P> 0.05) between treatments. However, the highest average value was found for the application of swine manure, and it corroborates with Gonçalves Júnior (2009), who found that swine manure provided efficacy in sugarcane, compared to mineral sources.

The results of crude protein were low from a nutritional point of view and corroborate to those observed by Calheiros et al. (2012) (3.13%) and Oliveira et al. (2012) (2.44%) when evaluating with sugarcane varieties. This frames the low crude protein content as an intrinsic characteristic of this culture. According to Siqueira, Roth, Moretti, Benatti, and Resende (2012), this is a characteristic considered as one of the biggest obstacles to the adoption of sugarcane as a bulky food for ruminants and there is, therefore, a need to be corrected with mineral supplementation.

As for neutral detergent fiber, it was observed that there was an increase when swine manure was used as nitrogen fertilizer, however there was no significant difference (P> 0.05). The values found are within those found in the literature. According to Silva, Ferreira, and Ruas (2007) it is not recommended to offer sugar cane as food to animals, when it has values of fiber in neutral detergent above 52%, as high NDF values can restrict food intake, and affect animal performance.

According to Giacomini et al. (2014), the neutral detergent fiber of sugarcane has low digestibility, being on average 40%, so the lower this value, the better the quality of this roughage. It is worth remembering that, on average, the NDF contents for this study were 42.8%, thus being recommended as animal food.

The values of acid detergent fiber found in this study (average of 40.41%) were higher than that found by Voltolini et al. (2012) for this same variety (27.4%), but in cane-plant. Thus, it can be said that the sugarcane on the field lost quality overtime, in relation to the ADF. It is likely that there was mobilization of soluble carbohydrates for a new phase of vegetative growth, increasing the participation of fiber in acid detergent in the analysis.

The lignin contents did not differ statistically (P> 0.05) for the evaluated treatments. The overall average was 6.3%, which was similar to that found by Oliveira et al. (2012) (6.6%), when studying four varieties of sugarcane. Silva et al., (2019) found 2.5% lignin content for this same variety (RB92579), in plant cane. These results confirm that forage plants undergo changes in their chemical composition, during the growing cycle, where there is an increase in the deposition of fibrous constituents at the expense of potentially digestible components.

According to Morais, Rosa, and Marcocini (2010), the knowledge of lignin content of a crop to be used as animal feed is important for determining its digestibility, since high levels of lignin negatively influence the digestibility of food by animals.

The organic nitrogen sources did not interfere in the sugarcane maturation, since there was no significant difference (P> 0.05) for the treatments, causing the variety to present high values of soluble solids, which are superior to those found by Bonomo et al. (2009) who evaluated 23 varieties of sugar cane with values averaging from 15.22 to 19.99.

The achievement of higher concentrations of soluble solids is influenced by the age of the sugarcane and is inversely correlated with the vegetative activity of the crop. According to Cruz et al. (2014), the evaluation of the sugar content in varieties destined for animal production is not only related to the point of harvest or sucrose production, but also has a close relationship with the NDF content. The lower the NDF / Brix ratio, the greater the nutritional value of the variety.

Cruz et al. (2014) concluded that the value of this relationship must be lower than 3.0; indicating that the variety will not limit the consumption of dry matter due to the NDF content. Carvalho et al. (2010) recommended a maximum of 2.7; it is worth remembering that the values found in this study ranged from 1.98 to 2.22 (P> 0.05).

The NDF / Brix ratio is an important variable to be considered when choosing the forage for feeding ruminants, since the low digestibility of the sugarcane fiber causes accumulation of undegraded material in the rumen, limiting voluntary consumption by the physical mechanism of ruminal repletion and thus compromising the animal's energy consumption (Carvalho et al., 2010).

3.2 Potential Degradation of Dry Matter (DM)

The values found for potential dry matter degradability showed an effect (P <0.05) for nitrogen sources (P = 0.0100), and time (P = 0.0001). There was no effect (P> 0.05) for the sources x time interaction (P = 0.0975) (Table 3).

Table 3. Degradation of dry matter (DEG DM) (%) of the sugarcane variety RB92579 due to treatments control (CON), urea (URE), swine manure (SM) and poultry litter (PL)

	Fertilizers			
	URE	CON	SM	PL
DEG DM (%)	66.40^{b}	67.83^{b}	68.55^{ab}	70.97^{a}
	Incubation times (hours)			
	72	24	6	
	75.29^{a}	67.09^{b}	62.93^{c}	

Means followed by different letters on the line differ from each other by the Tukey test (P <0.05).

The treatments of swine manure and poultry litter showed the highest levels of neutral detergent fiber (P> 0.05), however being compensated for by the low levels of acid detergent fiber, and a greater amount of soluble solids, resulting in a higher (P < 0.05) ruminal degradation of dry matter in relation to other treatments. It can be seen from the results obtained that the percentage of dry matter decreases with a greater amount of ruminal incubation time, this was a consequence of the action of microbial enzymes on the food.

Moreno et al. (2010) when offering sugarcane as a bulky food to lambs, obtained dry matter digestibility values similar to results found in this study (78.91%). These values are higher than those found by Macedo et al. (2011) (63.4%). Costa (2017), on the other hand, working with this same variety, found dry matter digestibility values of 58.8% for the first sock and

69.2% for the second sock. It should be emphasized that this work was carried out with sugarcane in the fourth punch, which suggests that the nutritional value of sugarcane is not impaired when the correct management of the cane field is carried out, including the use of organic sources of N.

4. Conclusion

The different organic sources of N did not interfere in the chemical composition and productivity of the sugarcane culture, however they presented better results in the dry matter in situ degradability, thus concluding that organic fertilizers can supply the needs of the crop and replace the fertilizers nitrogenous inorganics.

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