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Sources and rates of nitrogen fertilizer used in Mombasa guineagrass in the Brazilian Cerrado region

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Brazilian Cerrado is constituted largely by extensive grazing. In this region, livestock production indices are low, because the producers do not perform a soil amendment. The aim of this work was to study a pasture with high production potential using sources and rates of nitrogen (N). Nitrogen sources used were: Ammonium nitrate, ammonium sulfate, ammonium sulphonitrate, sulfammo and urea applied on the basis of 100 kg ha^{-1} per harvest, and N rates (0, 50, 100, 150 and 200 kg ha^{-1} per harvest), using urea as source, in five harvests. The forage used was [*Panicum maximum* (syn. *Megathirsus panicum*) cv. Mombaça], and were evaluated: Dry matter yield (DMY), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF). Dry matter yield increased on the second harvest, as a function of N rates. Acid detergent fiber and NDF concentrations there were no significant to the sources, and no adjustment with increasing of N rates. Crude protein content showed no adjustment for the N rates, as well as the N sources were not significant. Because the N performance, we recommend the urea, as this is more affordable and the application of 50 kg ha^{-1} of N for the maintenance of the Mombasa guineagrass.

Key words: Acid detergent fiber, crude protein, dry matter yield, neutral detergent fiber, *Panicum maximum*.

INTRODUCTION

Brazil is a leading meat producer worldwide because, in addition to its favorable climate, it has an abundance of land and vegetation. However, the Brazilian cattle industry faces seasonal fodder production and nutritional pasture deficiencies, the basis of its production system (Figueiredo et al., 2007). In general, there is excess production during the rainy season and shortage in the dry season. There are many grass species used for pasture in Brazil and due to its high DMY potential and good animal feed quality *Panicum maximum* is one of the most widely used for cattle (Corrêa and Santos, 2003).

Proper soil fertility management and understanding the nutritional requirements of this grass are extremely important for pasture management, which is reflected by higher food yield and availability for animals. The use of fertilizers can significantly increase forage production, providing greater capacity and thus resulting in higher milk and meat production per unit of area used (Pereira

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et al., 2011; Iwamoto et al., 2015). Additionally, it can also provide other supplementary effects that increase the efficiency of the system as a whole, such as the production of silage or hay to be used during the dry season (Cecato et al., 2001).

It is known that of all mineral nutrients, N is quantitatively the most important for plant growth. It is also a major nutrient to intensify grass yield, since it is an essential constituent of proteins and directly interferes in the photosynthesis process by its participation in the chlorophyll molecule (Moreira et al., 2005; Costa et al., 2008; Oliveira et al., 2010). In most studies, N has provided immediate and visible increase in forage production, this is because the amount of N available from the soil, from organic matter, does not seem to be enough to adequately provide or meet the needs of forage plants (Batista et al., 2014; Dupas et al., 2010; Hancock et al., 2011; Silva et al., 2011, 2013). Therefore, studies on the behavior of N in the soil-plant system are very important, especially if conducted under different pasture management conditions and at different times of the year, thereby reducing losses and increasing the efficiency of using N fertilizers for forage.

The most used source of N is still urea, by having more N per kilogram of product, however, is that the source can more easily be lost volatilization of ammonia (N-NH_3). To minimize these losses, the urea can be coated with polymers, have the urease inhibitor or nitrification inhibitor, thus slowing the release of N-NH_3. In addition there are other urea nitrogen sources such as ammonium nitrate has the form of 50% of N-NH_4^+ and 50% of N-NO_3^- and incorrect operation can result in leaching of N-NO_3^-; ammonium sulfate contains N and sulfur (S) and has acidifying effect to the soil; the ammonium sulphonitrate contain N and S has the nitrification inhibitor for minimize the leaching losses of N-NO_3^- (Cantarella, 2007).

Silveira et al. (2015) working with N rates (0, 60 and 120 kg ha^{-1} per year) and N sources (ammonium nitrate, ammonium sulfate, urea, urea treated with Agrotain, urea with urease inhibitor and ammonium sulphonitrate) for *Paspalum notatum* for three years, observed that the DMY increased linearly with rates of N and to the sources of N, occurred only difference for the second year of studies when used ammonium nitrate, reducing DMY compared with the other sources. Bennett et al. (2008) working with sources of N (ammonium sulfonitrate, ammonium sulfate and urea) and N rates (0, 50, 100, 150, 200 kg ha^{-1} by harvesting) for Marandu palisadegrass (*Brachiaria brizantha* cv. Marandu), observed that the sources of N did not affect DMY, only with the increase of N rates was increased DMY.

Therefore, this work studies the sources of N (ammonium sulphonitrate with nitrification inhibitor (Entec), sulfammo, ammonium nitrate, ammonium sulfate and urea), as well as N rates using urea as source, in the forage species [*P. maximum* (syn. *Megathirsus panicum*) cv. Mombaça], grown in the lower latitude Cerrado regions.

MATERIALS AND METHODS

The experiment was conducted at the School Farm, Research and Extension at the "Júlio de Mesquita Filho" University - Campus of Ilha Solteira - São Paulo State (20° 21' S and 51° 22' W), at an altitude of 326 m in an area previously occupied by *P. maximum*. Soil of the area was classified as Dark Red Alfisol (EMBRAPA, 2013), of sandy texture. The climate is characterized as humid subtropical climate (rainy in Summer and dry in Winter), according to the Köppen classification (Köppen and Geiger, 1928) and total rainfall, average and minimum temperature, average global radiation and average net radiation for 5 harvests shown in the Figure 1.

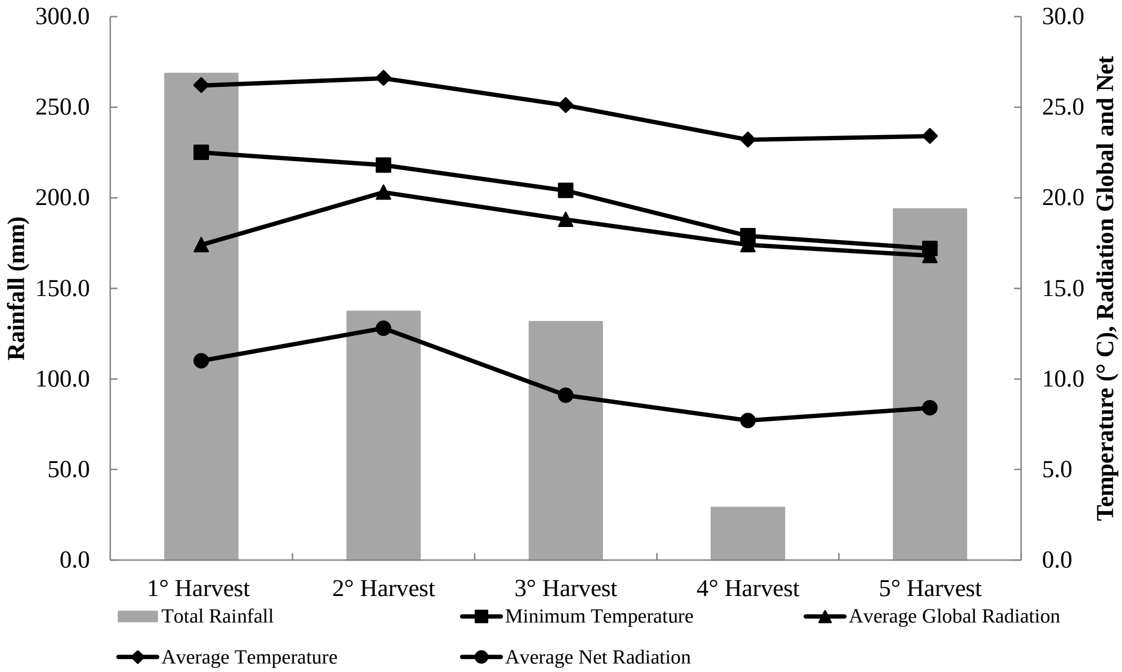
The soil chemical characteristics were determined according to Raij et al. (2001), before the experiment presented the following results: Phosphorus (P) resin = 13 mg dm^{-3}, pH determined in $CaCl_2$ (0.01 mol L^{-1}) = 5.2, potassium (K), calcium (Ca), magnesium (Mg), hydrogen + aluminum (H+Al) and exchange cation (EC) = 2.2, 35.0, 7.0, 16.0 and 60.2 $mmol_c$ dm^{-3}, respectively.

The area was prepared with one plowing and two harrowings and the Mombasa guineagrass was sown by direct seeding in January 2006. For the grass, the soil fertility was corrected by applying 20 kg ha^{-1} of N (urea - 45% of N). As for the P and K these were based on theoretical rates to achieve values of 30 mg dm^{-3} of P and K at 5% of the EC according to Werner et al. (1997), using simple superphosphate (SS - 18% of P_2O_5) and potassium chloride (KCl - 60% of K_2O) as sources.

The experimental design was randomized blocks with four replications, with five N sources: Urea (45% of N), as it is the most widely used N fertilizer and with possible loss of N-NH_3 by volatilization; ammonium sulphonitrate (26% of N and 13% of S), with nitrification inhibitor (Entec®); ammonium nitrate (32% of N) as the sole source of N; ammonium sulphate (18% of N and 22% of S) to verify the combined effect of N and S, since Entec and Sulfammo have S in their constitution; and Sulfammo (26% of N and 11% of S), with urea coated with seaweed waste, for the gradual release of N. Urea was used in five rates of N (0, 50, 100, 150 and 200 kg ha^{-1} per harvest), to verify the efficiency of the other N fertilizers, which were tested in a single rate to provide 100 kg ha^{-1} of N, per harvest, for each source. Each plot had an area of 6.0 m^2 (3 × 2 m), with 1 m spacing between them.

The harvests were made from February 19, 2010 until October 22, 2010, with fertilizing performed at every three harvests, supplying 40 kg ha^{-1} of K in every area. These harvests were performed manually at 30 cm (Carnevalli et al., 2006) above the ground in random locations within each plot, delimiting the area of 0.5 m^2 (metal quadrate of 1.0 × 0.5 m) for cutting and at time intervals according to pasture growth. The harvested forage was packed in paper bags and then dried in a forced air circulation oven, at a temperature of around 65°C, for 72 h. Next, the samples were weighed to quantify the DMY that was produced in the representative area and then grounded in a Wiley type mill equipped with a 1 mm sieve. The remaining grass portions were cut with a mechanical shredder and removed from the plots. After each forage harvest, the reaped material was removed from the area and the N rates applied to the grass in each plot, according to the treatment.

Dry matter yield of the Mombasa guineagrass was calculated based on the amount of green mass (kg m^{-2}), percentage of original dry mass and harvested area. Neutral detergent fiber, ADF and CP concentrations were also determined, using the methodology described by Silva and Queiroz (2002). For the determination of total nitrogen (TN) digestion was the sulfuric acid and the analytical



1st harvest - February 15th 2010; 2nd harvest - March 16th 2010; 3rd harvest - April 21th 2010; 4th harvest - May 20th 20 and the 5th harvest - October 22th 2010.

Figure 1. Total rainfall, average and minimum temperature, average global radiation and average net radiation for the 5 harvests of Mombasa guineagrass. Data were collected from the metereological station located in the School Farm, Research and Extension at the "Júlio de Mesquita Filho" University - Campus of Ilha Solteira, São Paulo State, 2010.

method was the micro-Kjeldahl. Crude protein concentration was calculated by multiplying the concentration of TN by 6.25.

All data underwent analysis of variance (F test), using the Tukey's test for the N sources to compare the means, and performing regression analysis for the N rates were applied through the statistical application Sisvar (Ferreira, 2011).

RESULTS AND DISCUSSION

Dry matter yield was not affected ($p<0.05$) by N rates in all harvests, except for the second harvest, where there was linear increase with N rates, it can be seen that the fertilization with 200 kg ha^{-1} of N resulted in an average yield of 44%, higher than the control (Table 1). Other studies showed that N fertilization significantly increases DMY in forage (Primavesi et al., 2006; Benett et al., 2008; Dupas et al., 2010; Batista et al., 2014). This shows that the soil where the experiment was conducted still had N reserve to nourish the plants to the productivity level achieved. Nevertheless, it is emphasized that compared to control (without N application) of this forage in the average of the five cuts, there were increases of 21.45 and 27.21%, respectively, for the rates of 50 and 100 kg ha^{-1} of N in the form of urea.

On the other hand, the dry matter biomass produced was satisfactory to ensure the stability of grass and animal production, since these values are higher than the 1600 kg ha^{-1} rate, which is proposed by Mott (1984) to ensure satisfactory forage intake.

As for the different sources (Table 1), no significant difference was found in any of the Mombasa guineagrass harvests for DMY. The same was observed by Silveira et at. (2015), who used the sources: ammonium nitrate, ammonium sulphate, urea, urea treated with Agrotain, Super U and ammonium sulphate nitrate and 3 N rates (0, 60 or 120 kg ha^{-1} per year) applied to Tanzania guineagrass (*P. maximum* cv. Tanzania), where there were no significant differences in the DMY. In contrast, Costa et al. (2010), working with Marandu palisadegrass and applying two N sources (ammonium sulfate and urea), observed that ammonium sulfate resulted in greater DMY than urea, in all rates and years evaluated. Crude protein concentrations increased with increase in N rates in all harvests, which were adjusted to linear regression, except in the first one (Table 1).

These results are consistent with those obtained by Dupas et al .,(2010) (using marandu palisadegrass), Barros et al. (2002) (using Tanzania guineagrass), Silveira et al. (2015) (using *Paspalum notatum*) and Freitas et al. (2007) (using *P. maximum*), who found linear increase in CP concentration due to the increase in N rates.The different N sources did not affect the CP concentration ($p<0.05$). These results disagree from those found by Benett et al. (2008), who working with

Table 1. Means, coefficients of variation (C.V.), Tukey's test and regression equations relating to the dry matter yield (DMY) and crude protein (CP) of Mombasa guineagrass in five harvests.

N rates (kg ha^{-1})	1st harvest 02/19/2010	2nd harvest 03/16/2010	3rd harvest 04/21/2010	4th harvest 05/20/2010	5th harvest 10/22/2010
			DMY (kg ha^{-1})		
0	3250	709 $^{(1)}$	1575	1622	1662
50	3675	1129	1950	1961	2128
100	3800	1237	2025	2243	2340
150	3825	1164	2000	1936	2447
200	3900	1253	1925	1907	1938
C.V. (%)	14.68	19.27	15.44	17.04	27.10
N Sources (100 kg ha^{-1} of N)					
Ammonium sulphonitrate	2800^{a}	980^{a}	2225^{a}	1856^{a}	2494^{a}
Ammonium nitrate	3125^{a}	1111^{a}	2100^{a}	1932^{a}	2128^{a}
Ammonium sulfate	2675^{a}	1137^{a}	2050^{a}	2013^{a}	2644^{a}
Sulfammo	4125^{a}	1355^{a}	1700^{a}	1902^{a}	2639^{a}
Urea	3800^{a}	1237^{a}	2025^{a}	2243^{a}	2340^{a}
L.S.D. (5%)	1332	622	507	854	694
C.V. (%)	21.46	28.45	13.38	22.86	15.10
(kg ha^{-1})			**CP (gkg^{-1} DM)**		
0	64.7	110.9$^{(2)}$	114.4$^{(3)}$	130.4$^{(4)}$	83.2$^{(5)}$
50	73.2	129.1	127.5	142.2	92.8
100	66.6	151.9	128.8	150.9	96.9
150	75.9	149.4	147.2	163.6	100.5
200	88.2	147.2	140.7	164.1	113.3
C.V. (%)	15.29	9.17	7.89	6.24	8.84
N Sources (100 kg ha^{-1} of N)					
Ammonium sulphonitrate	77.8^{a}	152.9^{a}	95.7^{a}	176.8^{a}	103.7^{a}
Ammonium nitrate	76.3^{a}	138.8^{a}	145.1^{a}	161.9^{a}	115.1^{a}
Ammonium nitrate	76.6^{a}	147.2^{a}	164.1^{a}	172.6^{a}	115.1^{a}
Sulfammo	72.8^{a}	132.5^{a}	141.6^{a}	169.6^{a}	98.9^{a}
Urea	66.6^{a}	151.9^{a}	128.8^{a}	150.9^{a}	96.9^{a}
L.S.D (5%)	3.85	4.22	14.81	4.10	4.10
C.V. (%)	11.40	6.63	24.50	5.55	8.62

$^{(1)}$ DMY = 874.30 + 2.24 N (R^2= 0.63); $^{(2)}$ CP = 118.00 + 0.20 N (R^2 = 0.78); $^{(3)}$ CP = 119.00 + 0.14 N (R^2 = 0.72); $^{(4)}$ CP = 134.00 + 0.18 N (R^2 = 0.92); $^{(5)}$ CP = 84.00 + 0.14 N (R^2 = 0.92). Means followed by equal letters in the column do not differ among themselves by Tukey's test at 5% level of probability.

Marandu palisadegrass and using urea, ammonium sulphonitrate and ammonium sulfate as N sources, reported that the use of ammonium sulphonitrate provided higher CP concentrations, differing only with urea, in the first harvest. While in the second harvest, the N sources did not differ. As for the third harvest, ammonium sulfate had the lowest CP concentration, statistically differing from the ammonium sulphonitrate and urea sources.

Crude protein concentration of plants is associated with the soil N availability. However, N fertilization had no significant effect ($p>0.05$), probably due to the dilution effect caused by this system's material accumulation. According to Soest (1994), CP forage contents less than 70 g kg^{-1} of DM cause digestion reduction, due to inadequate N levels for the microorganisms in the rumen, reducing their population and, consequently, reducing digestibility and dry matter intake. Thus, higher concentrations of CP are needed to meet the animal protein requirements. In this work, it was observed that CP concentrations of Mombasa guineagrass, when fertilized, showed optimal concentrations, reaching

Table 2. Means, coefficients of variation (C.V.), Tukey's test and regression equations relating to the neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentration in Mombasa guineagrass in five harvests.

N Rates (kg ha^{-1})	**1st harvest 02/19/2010**	**2nd harvest 03/16/2010**	**3rd harvest 04/21/2010**	**4th harvest 05/20/2010**	**5th harvest 10/22/2010**
			NDF (g kg^{-1} DM)		
0	697.3	645.0	685.2	584.3	635.6
50	701.0	565.4	691.1	592.4	641.8
100	689.9	675.6	664.4	594.2	654.5
150	711.3	669.4	669.3	596.6	645.9
200	728.9	654.1	680.5	599.7	638.8
C.V. (%)	3.97	11.00	2.90	1.96	2.33
N sources (100 kg ha^{-1} of N)					
Ammonium sulphonitrate	631.8^{a}	662.8^{a}	670.4^{a}	611.5^{a}	654.5^{a}
Ammonium nitrate	728.3^{a}	643.4^{a}	697.0^{a}	601.8^{a}	624.6^{a}
Ammonium sulfate	722.9^{a}	672.4^{a}	688.5^{a}	587.9^{a}	661.9^{a}
Sulfammo	711.8^{a}	665.9^{a}	666.1^{a}	590.9^{a}	663.1^{a}
Urea	689.9^{a}	675.6^{a}	664.4^{a}	594.2^{a}	654.5^{a}
L.S.D. (5%)	24.45	5.26	5.88	8.20	8.43
C.V. (%)	7.88	1.78	1.95	3.10	2.91
(kg ha^{-1})			**ADF (gkg^{-1} DM)**		
0	358.6	311.6	335.7	273.0	334.2
50	355.2	240.1	346.3	276.6	336.3
100	348.4	305.4	327.9	283.4	333.4
150	364.7	299.9	324.3	263.4	321.0
200	353.7	300.5	324.8	274.4	320.8
C.V. (%)	4.59	15.17	3.49	2.82	4.02
N sources (100 kg ha^{-1} of N)					
Ammonium Aulphonitrate	318.1^{a}	301.4^{a}	327.4^{a}	278.6^{a}	329.6^{a}
Ammonium Nitrate	362.9^{a}	292.9^{a}	333.1^{a}	291.2^{a}	309.9^{a}
Ammonium Nitrate	358.9^{a}	301.6^{a}	330.0^{a}	266.0^{a}	329.0^{a}
Sulfammo	357.2^{a}	309.2^{a}	321.1^{a}	275.6^{a}	336.8^{a}
Urea	348.4^{a}	305.4^{a}	327.9^{a}	283.4^{a}	333.4^{a}
L.S.D. (5%)	14.33	2.81	5.26	8.01	4.10
C.V. (%)	9.29	2.09	3.61	6.46	2.81

Means followed by equal letters in the column do not differ by Tukey's test at 5% level of probability.

values of 164.1 g kg^{-1} of DM, when fertilized with 200 kg ha^{-1} N. These higher concentrations of CP due to N fertilization indicate that it cans result in increased support capacity and animal live weight gain (Dias et al., 1998).

Neutral detergent fiber concentration negatively correlated with the animals voluntary intake and with forage quality, showed no significant differences for the different N sources and N rates (Table 2). These results corroborates with Quadros and Rodrigues (2006), who worked with N rates of 101.5, 145, 188.5 and 232 kg ha^{-1} applied to Tanzania guineagrass and Mombasa guineagrass, verifying that the NDF concentration of leaves and stems did not undergo a well defined affect in terms of N fertilization. Vitor et al . (2009) also obtained no significant response for the NDF, with regards to increasing N rates applied to Elephant grass (*Pennisetum purpurem*) during the rainy season, attributing it to the accelerated plant maturity, when in favorable weather conditions associated to N application, thereby limiting their beneficial effect on the NDF concentration.

Costa et al. (2011) found negative linear effects of N rates on NDF of Xaraés grass (*Brachiaria brizantha* cv. Xaraés*)* Castagnara et al. (2011) working with three tropical forage grasses (Mombasa, Tanzania guineagrass and *Brachiaria* sp. cv. Mulato) and four N rates (0, 40, 80 and 160 kg ha^{-1}), observed that the NDF concentration were affected significantly by N rates, fitting a quadratic equation. The differences in the various experiments are due to soil and climate conditions, management of the species used and the productivity achieved.

According to Soest (1994), NDF concentration is the most limiting factor to forage intake, with levels of cell wall constituents over 55 to 60%, in dry weight, negatively correlated with forage intake. Thus, in general, it is observed that for animal intake the Mombasa guineagrass is less attractive forage.

Neutral detergent fiber concentration, the concentrations of ADF in Mombasa guineagrass and which are negatively correlated with digestibility, also was not affected by N rates (Table 2). The same was found by Vitor et al. (2008) working with Brachiaria grass with N rates (0, 50, 100 and 150 kg^{-1} ha^{-1} per year), concluding that the ADF concentrations were not affected by N fertilization. Similarly, Ribeiro et al. (1999), working with Elephant grass found little or no influence of N fertilization on the NDF and ADF concentrations of forage. Rocha et al. (2002) also found no significant difference for the ADF values obtained, when working with grasses of the genus *Cynodon,* and with N rates (30, 60 and 120 kg ha^{-1}). In this study, no significant differences for the sources of N were found. However, Costa et al. (2004) found lower concentrations of the ADF in Tanzania guineagrass in the rainy season with the application of 450 kg N ha^{-1} compared to 300 and 150 kg ha^{-1}, which did not differ among them. It should be noted that ADF concentrations above 400 g kg^{-1} are considered as limiting for digestibility (Soest, 1994). In this work, regardless of the rates or sources of N, ADF concentrations less than 400 g kg^{-1} of DM were obtained (Table 2). Thus, in this study, it can be inferred that the Mombasa guineagrass is good digestibility forage.

Conclusions

1. Dry matter production increased with the application of N rates only in the second harvest, of the five harvests performed. Sources of N provided the same behavior.
2. Crude protein concentration increased with N rates in four of the five harvests; however, the sources of N did not affect it. Nitrogen rates did not influence the ADF and NDF concentrations, as well as the sources used.
3. Due to the fact there are no differences among sources, in all evaluations, the use of urea is recommended, as this is the most affordable at a dose of 50 kg ha^{-1} of N, as maintenance and guarantee for good CP concentrations.

Conflict of Interest

The authors have not declared any conflict of interest.

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