YIELD AND QUALITY OF ELEPHANT GRASS BIOMASS PRODUCED IN THE CERRADOS REGION FOR BIOENERGY

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ABSTRACT: The objective of this study was to evaluate the performance of two genotypes of elephant grass, fertilized with and without N, for biomass production for energy use under the edaphoclimatic conditions of the Cerrado. The genotypes Roxo and Paraíso, grown in a field experiment in a Latosol in the Cerrado region were evaluated for biomass yield, nitrogen accumulation, C:N and stem:leaf ratios, fibre, ash and P and K contents and calorific value. The accumulated dry biomass ranged from 30 to 42 Mg ha^{-1} and showed no response to nitrogen fertilization with the lowest biomass obtained by the genotype Paraíso and the highest by Roxo. The total N accumulation followed the same pattern as for dry matter, ranging from 347 to 539 kg N ha^{-1}. C:N and stem:leaf ratio of the biomass produced did not vary with treatments. The fibre contents were higher in genotype Paraíso and the highest levels of ash in the genotype Roxo. The K content in the biomass was higher in genotype Roxo and P did not vary between genotypes. The calorific value averaged 18 MJ kg^{-1} of dry matter and did not vary with the levels of N in leaves and stems of the plant. Both genotypes, independent of N fertilization, produced over 30 Mg ha^{-1} of biomass under Cerrado conditions.

KEYWORDS: *Pennisetum purpureum*, bioenergy, nitrogen fertilizer.

PRODUÇÃO E QUALIDADE DA BIOMASSA DE CAPIM-ELEFANTE PRODUZIDO EM AMBIENTE DOS CERRADOS PARA FINS ENERGÉTICOS[1]

RESUMO: O presente trabalho objetivou avaliar o desempenho de dois genótipos de capim-elefante para produção de biomassa para uso energético, em condições edafoclimáticas do Cerrado, fertilizados, ou não, com N. Avaliaram-se os rendimentos de biomassa, o acúmulo de nitrogênio, as relações C/N e colmo/folha, os teores de fibra, as cinzas da biomassa, os teores de K e P da biomassa e poder calorífico dos genótipos Paraíso e Roxo, cultivados em Latossolo, na região de Cerrado. A biomassa seca acumulada variou de 30 a 42 Mg ha^{-1}, não havendo resposta à fertilização nitrogenada, sendo os menores obtidos com o genótipo Paraíso, e os maiores, com o Roxo. A acumulação total de N seguiu o mesmo comportamento da matéria seca, variando de 347 a 539 kg ha^{-1} de N. As relações C/N e colmo/folha da biomassa produzida não variaram com os tratamentos. Os teores de fibra foram maiores no genótipo Paraíso, e os teores de cinza, maiores no genótipo Roxo. O teor de K na biomassa de capim-elefante foi maior no genótipo Roxo, e o de P não variou entre os genótipos. O poder calorífico foi, em média, de 18 MJ kg^{-1} de matéria seca, e não variou em função dos teores de N nas folhas e nos colmos da planta. Ambos os genótipos, independentemente da fertilização com N, produzem acima de 30 Mg ha^{-1} de biomassa, em condições de Cerrado.

PALAVRAS-CHAVE: *Pennisetum purpureum*, bioenergia, fertilização nitrogenada.

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INTRODUCTION

The production of alternative energy from plant biomass is one of the greatest challenges for reducing dependence on fossil fuels, such as oil and coal, which are finite sources and contribute to the greenhouse effect on the planet. In this context, the biomass of elephant grass (*Pennisetum purpureum* Schum.) has the potential to be used in biofuel production, in the form of charcoal, alcohol, methane or even for direct burning, due to the extremely high positive energy balance (ANDERSON et al., 2008; JAKOB et al., 2009; LEE et al., 2010; LIMA et al., 2011; MORAIS et al., 2012; SAMSON et al., 2005; SMEETS et al., 2009; STREZOV et al., 2008).

Elephant grass is highly efficient in fixing atmospheric CO_2 and is able to accumulate more than 60 Mg ha^{-1} of dry matter per year (MORAIS et al., 2009b). Another important feature of elephant grass in use for energy production is its similarity to crushed sugarcane in high fibre content (~ 65%), an important characteristic for the calorific value of the biomass (MORAIS et al., 2009a; TOLEDO, 2009). According to OSAVA (2007) eucalyptus trees need seven years to reach a size worth cutting, while elephant grass offers two to four harvests per year owing to its fast growth.

MORAIS et al. (2009b, 2012) planted elephant grass in soils with low N availability and found a percentage of fibre above the minimum desirable for use as biomass for burning, although still lower than in other species used for this purpose, such as eucalyptus. But when one considers the productive potential and the possibility of more than one cut per year, elephant grass has great potential for this purpose. MORAIS et al. (2009b) when studying clones of elephant grass, among them Cameroon, Gramafante and BAG-02, found average annual yields of 36; 30 and 33 Mg ha^{-1} of dry matter, respectively. Likewise, QUESADA (2005) observed accumulation of dry matter up to 30 Mg ha^{-1} for the Cameroon and Gramafante genotypes after 8 months in low fertility soil and without application of N. These yields were observed in the Atlantic Forest region, where the annual rainfall and mean temperature are adequate to allow the growth of grass throughout the year. In this condition, two cuts are made of biomass per year with the highest yields observed in the summer (MORAIS et al., 2009b) the, hotter and wetter period.

Biomass production, especially in Brazil, stands out as an opportunity in the medium and long term for the production of alternative energy sources, because it disposes of land sufficient to achieve significant production (GOLDEMBERG, 2009). Thus, the Cerrado region has been exploited for food production, but there are companies interested in producing energy for various purposes from biomass. Elephant grass is an option for the region, but it is necessary to assess if in these edaphoclimatic conditions high levels of productivity would be maintained. In the Cerrado, rainfall is concentrated in the summer and winter is characterized by 4 to 6 months of drought, indicating that yields of grass above 30 Mg ha^{-1} should be achieved in a single cut, after the summer. Furthermore, soils have typically low availability of N one of the elements which most limits plant production, especially grasses. Elephant grass can benefit relatively well from the biological N_2 fixation a source of more than 30% of N in shoots of this species according to MORAIS et al. (2009b), but BNF does not fulfill all the crop´s N requirement the use of N fertilizer may be the solution for sustaining high productivities over time. In this case nitrogen fertilization contributes negatively to the energy balance of the culture (SAMSON et al., 2005) and also leads to less production of a fibrous material which would imply a reduction in calorific value, although these effects have not yet been evaluated.

The objective of this study was to evaluate two genotypes of elephant grass in yield and quality characteristics of biomass in the Cerrado region conducted with and without the addition of nitrogen fertilizer.

MATERIAL AND METHODS

The study was conducted at the Federal University of Tocantins, located in the municipal district of Gurupi , state of Tocantins (TO). The statistical design corresponded to a split plot, with the main plot consisting of two genotypes of elephant grass (Paraíso and Roxo), and the sub-plot of nitrogen (0 and 100 kg N ha^{-1} as urea) with four replications. The area was on a Typic Hapludox (EMBRAPA, 2006). The soil analysis was done following the method proposed by EMBRAPA (1997), on samples taken at a depth of 0-20 cm, with the following values: 1.79% organic matter; 0.11% nitrogen; 1.06% carbon; 5.75 pH (H_2O); 0.01cmol$_c$ dm^{-3} aluminum; 3.19 cmol$_c$ dm^{-3} calcium + magnesium; 62.7 mg dm^{-3} potassium; 5.5 mg dm^{-3} Phosphorus. The plots consisted of 4 rows with 5 m long and 1 m row spacing, totaling an area of 20 m^2 per plot.

Potassium chloride and single superphosphate were applied at the bottom of the furrow in quantities equivalent to 100 kg ha^{-1} of K_2O, and 100 kg ha^{-1} P_2O_5, respectively. The experiment was planted in early December 2008, and the first cut was made at 180 days after planting. During the experiment mechanical weeding was performed as required.

The fresh weight of the biomass of each plot was determined without separating stem and leaves. Samples were removed to a drying oven at 65 ºC to constant weight to determine the percentage of dry matter of plants. The proportion of stem and leaf in each genotype was calculated from five plants collected randomly within each plot, at the time of cutting. Plant samples were passed at a Wiley mill type (2 mm sieves) and then on the roller mill until pulverization for analysis of total-N content.

Analyses of the fibre content (detergent - NDF) and ash were carried out as described by SILVA (1990). The carbon/nitrogen (C/N) ratios were calculated based on estimated C content of 45% of biomass and the stem/leaf (S/L) ratio according to the mass of dry matter measured for each part. Analyses of nutrients (phosphorus and potassium) were conducted following the method described by SILVA (1999), based on nitro-perchloric digestion.

Gross calorific value which is defined as the amount of energy in the form of heat released by the combustion of a mass unit of a material, including the energy required for evaporation of water contained in the material (QUIRINO et al., 2005) was determined by bomb calorimetry. These determinations were carried out at Embrapa Forestry, Curitiba, state of Paraná, Brazil. The tests were done according to ABNT NBR 8633/84 and the calorimeter manual PARR 1201. The samples used were chosen in function of the concentration of total-N in stems and leaves. For each plant part 10 samples were analysed. In leaf samples the concentration ranged from 1.25 to 2.11% of N and stems from 0.87 to 1.59% of N.

Statistical procedures were those of the statistical package SAEG 9.1 (UFV, 2007). Initially the normality and homogeneity of variances of errors were analysed by means of the tests of Lilliefors and of Cochran and Bartley, respectively. With the assumptions attended, analysis of variance were performed with application of the F test, and, for the variables in which the F test was significant, treatment means were compared by the Tukey HSD test ($p < 0.05$).

RESULTS AND DISCUSSION

The biomass productivity of the elephant grass, expressed in dry matter in the absence of nitrogen was of 30.0 and 37.3 Mg ha^{-1} for the genotypes Paraíso and Roxo, respectively. With the application of 100 kg of N ha^{-1}, the respective yields were 31.9 to 42.6 Mg ha^{-1} (Table 1). The application of nitrogen fertilizer did not increase grass yield, but the productivity of the Roxo genotype was significantly higher than Paraíso.

The production of leaves and stems was not affected by the addition of N (Table 1). No significant difference was observed between the studied genotypes with respect to the production of dry biomass of leaves, which ranged between 4.9 and 8.7 Mg ha^{-1}. The differences observed among genotypes for total plant biomass was explained by the higher stem yield. The Paraíso genotype produced between 25.1 and 26.3 Mg ha^{-1} of dry stems, while for Roxo yields of dry stems were between 30.3 and 33.9 Mg ha^{-1}.

Probably the biomass production of the Roxo genotype was superior to Paraíso because this genotype was planted as vegetative parts (setts), and Paraíso genotype was planted as seed. The germination and development of Paraíso genotype were relatively slower compared to Roxo genotype because of the existence of higher nutrient reserves in setts than in seeds.

TABLE 1. Dry matter yield (Mg ha^{-1}) of two genotypes of elephant grass, grown on the campus of the Federal University of Tocantins (Gurupi, TO - Brazil), 180 days after planting.

December 2008 to June 2009						
	Stem		Leaf		Total	
Amount of N (kg ha^{-1})	0	100	0	100	0	100
Paraíso	25.1 Ba	26.3 Ba	4.9 Aa	5.7 Aa	30.0 Ba	31.9 Ba
Roxo	30.3 Aa	33.9 Aa	7.0 Aa	8.7 Aa	37.3 Aa	42.6 Aa
Mean	27.7	30.1	5.9	7.2	33.6	37.2
C.V. %	20.43	20.43	28.36	28.36	18.61	18.61

In column, the uppercase, and in row, the lowercase letter, mean values followed by the same letter do not differ by Tukey test ($p < 0.05$).

The yields obtained with only one cut in the rainy season in the Cerrado region may be considered excellent, with reference to the performance of selected genotypes as high biomass production in Atlantic Forest (MORAIS et al., 2009b, 2012). Approximately 72% of the plant biomass of shoots corresponds to stem, which is very important due to the high fiber content, lignin, and other components important for a good quality of biomass for energy.

The lack of response to the use of N-fertilizer should be interpreted with caution but it is indicative of the high efficiency of elephant grass in the absortion and use of this nutrient, either directly from the soil or by the contribution of diazotrophic bacteria associated with plant (MORAIS et al., 2012). The results are very promising because the observed behavior contributes to reinforce the importance of saving N-fertilizer on the production system, because it is an input that demands a lot of fossil energy in its production. Therefore, any savings in their use will contribute to the biomass produced to present a more positive energy balance.

TABLE 2. Total N accumulation (kg ha^{-1}) of two genotypes of elephant grass, grown on the campus of the Federal University of Tocantins (Gurupi, TO), 180 days after planting.

December 2008 to June 2009						
	Stem		Leaf		Total	
Amount of N (kg ha^{-1})	0	100	0	100	0	100
Paraíso	268.7 Aa	304.7 Ba	78.5 Aa	98.1 Aa	347.2 Aa	402.8 Ba
Roxo	354.6 Aa	414.4 Aa	101.9 Aa	124.4 Aa	456.5 Aa	538.9 Aa
Mean	311.6	359.5	90.2	111.2	401.8	470.8
C.V. %	29.39	29.39	26.69	26.69	25.04	25.04

In column, the uppercase, and in row, the lowercase letter, mean values followed by the same letter do not differ by Tukey test ($p < 0.05$).

The accumulation of N in the shoots area of the plants of both genotypes followed the dry matter production. There was no significant response to the application of nitrogen fertilizer for either genotype. However, Roxo differed from the Paraíso genotype accumulating about 415 kg ha^{-1} of N in stems and 540 kg ha^{-1} of N in the whole shoot area, while the Paraíso genotype accumulated 305 kg ha^{-1} of N in the stems and 400 kg ha^{-1} of N in whole shoot (Table 2). The lack of significant effect of nitrogen fertilization may be related to a high soil N supply and/or high dependency of N_2 fixation. The concentration of N in the shoots of the plant were close to 13 g kg^{-1}, resembling to those obtained by MORAIS et al. (2009a, 2012), but the high plant productivity boosted the amount of N accumulated by plants.

The high potential demonstrated by culture in accumulating N in shoot area must also have been influenced by edaphoclimatic conditions of the region, with over 1,200 mm rainfall accumulated during the conduction of the experiment and with a mean temperature of approximately 26 ºC. QUESADA et al. (2001) studying the potential of elephant grass genotypes for biomass production in the rainy season, also found accumulations of N ranging between 370 and 540 kg of N per ha^{-1}, and no significant influence of the application of 100 kg ha^{-1} of N fertilizer was observed.

For the C/N ratio and the stem/leaf ratios significant differences were not observed between nitrogen levels or between genotypes. The Paraíso genotype presented, in absolute values, higher C/N and S/L ratios when compared to Roxo genotype (Table 3). As the stems concentrate more fibre, genotypes with high biomass productivity associated to a high proportion of dry matter of stems in the total produced are more promising to material of high calorific value. In this sense, the higher the C/N ratio typically the more fibrous and lignified the material is, i.e., gives better conditions for the energetic use, and indicate a greater production capacity with less accumulated nitrogen.

It was observed significant differences among genotypes as fibre content (NDF) of the stems, considering the Paraíso genotype superior to the Roxo genotype (Table 4). According to QUESADA (2005), fibre values above 52% indicate good quality of these materials using for charcoal. No significant differences among genotypes for fibre content (NDF) in the leaves was observed.

There was also no response from the fibre content as a function of nitrogen fertilization, in either stems or leaves. MAGALHÃES et al. (2009) studying the effect of nitrogen and three genotypes of elephant grass, found mean contents of NDF around 70% with no significant effect of nitrogen fertilization. These values, along with the production of dry biomass (around 35Mg ha^{-1} in just six months of cultivation), corroborate the ability of the elephant grass materials studied have for energy production the replacement of coal or other traditional sources of energy (charcoal, gas, wood, etc.) (QUESADA, 2005).

TABLE 3. Carbon/Nitrogen (C/N) and Stem/Leaf (S/L) ratio of the biomass produce by two genotypes of elephant grass, grown at two different N fertilizer levels, on the campus of the Federal University of Tocantins (Gurupi, TO), 180 days after planting.

Genotype	Amount of N	December 2008 to June 2009	
	kg ha^{-1}	C/N	S/L
Paraíso	0	39.1 a	4.7 a
	100	37.0 a	5.5 a
Roxo	0	37.5 a	4.0 a
	100	35.6 a	4.4 a
Mean		37.3	4.6
C.V.%		11.48	23.46

In each column, mean values followed by the same letter do not differ by Tukey test ($p < 0.05$).

There was no significant difference in ash production due the amount of N applied in the leaves and stems of plants. However, in the absence of nitrogen, the percentage of ash from the Roxo genotype was significantly greater than that of the Paraíso genotype. This higher ash content may be explained by the higher K content in the stems and leaves of the Roxo genotype (Table 5). This condition was the result of good soil fertility where the study was conducted. QUESADA (2005), in a study of genotype selection of elephant grass in Acrisol, found ash content in leaves of Roxo genotype of 8.1%, and in the stem of 1.17%. MORAIS (2008) also working with elephant grass, found ash contents in the leaves between 1.76 and 3.79% and in stems, between 3.95 and 5%. Both studies were in soils and environments rather different to the soil used in this study, which showed good fertility.

TABLE 4. Fibre content in neutral detergent (NDF) and ash content in shoot tissue of two genotypes of elephant grass, grown at two different N fertilizer levels, on the campus of the Federal University of Tocantins (Gurupi, TO - Brazil), 180 days after planting.

	FDN (%)				Ashes (%)			
	Stem		Leaf		Stem		Leaf	
Amount of N (kg ha^{-1})	0	100	0	100	0	100	0	100
Paraíso	64.8 Aa	62.9 Aa	57.3 Aa	57.7 Aa	4.5 Ba	4.3 Aa	8.4 Ba	8.6 Aa
Roxo	53.3 Ba	51.4 Ba	58.6 Aa	57.0 Aa	9.4 Ab	7.6 Aa	10.0 Aa	9.1 Aa
Mean	59.0	57.1	57.9	57.3	6.9	5.8	9.2	8.8
C.V. %	7.44	7.44	6.06	6.06	33.33	33.33	9.84	9.84

In column, the uppercase, and in row, the lowercase letter, mean values followed by the same letter do not differ by Tukey test ($p < 0.05$).

It should be noted that high ash content is undesirable in the process of burning material for the production of energy and especially for producing charcoal for iron founding. SEYE (2003), comparing different biomass for the production of pottery, found ash content of 4.1% for sugarcane bagasse, 7.1% for sugarcane straw and 11.5% for the elephant grass, attributing the higher ash content of the grass to high applications of nitrogen fertilizer which ranged from 50 to 400 kg ha^{-1} of N per year. Materials with higher ash contents in their chemical composition are more release of volatile substances at higher temperatures. This is because the organic material interact with the inorganic material, leading to a slowing of the transfer of heat inside the particles and, consequently, allowing the diffusion of volatile before the complete combustion (SEYE, 2003). Beyond this point, RENDEIRO et al. (2008) state that the ash and residues from biomass combustion are composed of inorganic and metal substances, or slag, which may clog the furnace grates. However, slag formation it is not generally observed in fuels having ash contents of less than 6%.

The ash produced by the biomass may be a problem, but the use of biomass for direct combustion, in potteries, for example, makes possible the reuse of the ash for fertilization of the grass field thus diminishing external fertilizer inputs.

TABLE 5. Concentrations of K and P in the shoot area of two genotypes of elephant grass grown at two different N fertilizer levels, on the campus of the Federal University of Tocantins (Gurupi, TO - Brazil), 180 days after planting.

	K Value (g kg^{-1})				P Value (g kg^{-1})			
	Stem		Leaf		Stem		Leaf	
Amount of N (kg ha^{-1})	0	100	0	100	0	100	0	100
Paraíso	17.9 Ba	17.7 Aa	17.0 Aa	16.4 Aa	1.2 Aa	1.2 Aa	1.8 Aa	2.7 Aa
Roxo	39.7 Aa	33.5 Aa	17.7 Aa	17.0 Aa	1.3 Aa	1.4 Aa	2.6 Aa	1.9 Aa
Mean	28.8	25.6	17.3	16.7	1.2	1.3	2.2	2.3
C.V. %	33.94	33.94	15.48	15.48	17.33	17.33	28.75	28.75

In column, the uppercase, and in row, the lowercase letter, mean values followed by the same letter do not differ by Tukey test ($p < 0.05$).

The results of K and P analyses of the plant shoot tissue of elephant grass are presented in Table 5. For both nutrients evaluated (K and P), there was no significant response to the application of nitrogen fertilizer levels in relation to the accumulation of these nutrients in the tissues of elephant grass. The evaluation of K content in the stem, in the absence of nitrogen, showed that Roxo genotype obtained greater accumulation of this element in relation to Paraíso genotype, indicating genetic differences between the materials used in the study which was reflected in the ash content of the biomass. The phosphorus contents in the tissue of elephant grass were not different between genotypes.

The gross calorific value (GCV) measured in stems and leaves material of the plant of elephant grass was not correlated to the concentrations of nitrogen in the respective parts of the plant, yielding an overall mean of 17.15 MJ kg^{-1} (Figure 1). This result shows that the use of nitrogen fertilizer or planting in soil rich in available N which can produce biomass with high levels of protein, implies no significant change in fibre and lignin content to the point of reducing the calorific value of the biomass produced.

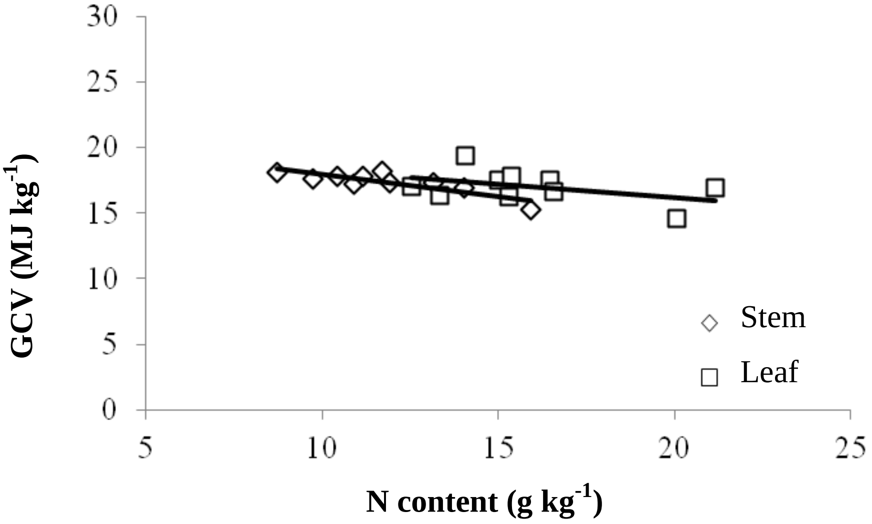

FIGURE 1. Gross Calorific Value (GCV) in function of the concentration of nitrogen in the stem and leaf of elephant grass cv. Paraíso, grown under different management conditions in the Cerrado region.

The value found for the gross calorific value of elephant grass is similar to that found by LIMA et al., (2007) in samples of eucalyptus, featuring individual trees of *E. benthamii* for energy use, finding a gross calorific value ranging around 21 MJ kg^{-1}. QUENÓ et al. (2011), studying the biomass production cost of eucalyptus and elephant grass for energy purposes, also found similar value for the gross calorific value of eucalyptus wood, ranging around 19 MJ kg^{-1}. QUIRINO et al., (2005), evaluated the calorific value of wood of 132 forest species and found values ranging between 14.02 and 22.00 MJ kg^{-1}, with an overall mean of 19.81 MJ kg^{-1}.

CONCLUSIONS

With just one cut after 180 days of growth the two genotypes Paraíso and Roxo showed dry biomass yield similar to those found under wetter conditions, and in the first year were not influenced by nitrogen fertilization with 100 kg N ha^{-1}.

The use of nitrogen fertilizer does not affect the quantity and quality of elephant grass biomass produced, especially the calorific value, which remains at high levels.

The ash content of the biomass produced is considered above that recommended for use in iron founding but these levels should pose no problem for direct burning.

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