Effect of Elephant Grass Genotypes to Bioenergy Production

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ABSTRACT

The study aimed to evaluate the agronomic characteristics of elephant grass (*Pennisetum purpureum* Schum.) genotypes on energy production in the combustion form. A randomized block design with 3 repetitions was used. The treatments were arranged in subdivided plots scheme, considering as a plot the genotypes and as subplots, the harvest season. The agronomic characteristics plant height (H), leaf length (LL), leaf blade width (LBW), stem diameter (SD), tillers number (TN), stem percentage (SP), dry matter yield (DMY) were evaluated. The rainy season provided greater H to elephant grass genotypes with height above 3.5 m. The average SP obtained by the genotypes was 68.21% and 67.21% to the first and second year of cultivation, respectively, which gives the biomass good quality of burning. The rainy season provided greater DMY comparing to the dry season. In the first year of cultivation there were genotypes with annual dry matter yield (ADMY) above 50 ton ha^{-1} year^{-1}, however, the non-maintenance of soil fertility promoted the reduction of 39.17% and 39.05% in the DMY and ADMY, respectively. Analyzing the agronomic characteristics, we conclude that the promising genotypes of elephant grass to produce energy in the form of direct combustion are CNPGL 91-25-1, Cubano Pinda, BRS Canará, Porto Rico and Mercker.

1. INTRODUCTION

Fossil fuels present environmental problems that alter the climate dynamics, as well as being a finite resource. Therefore, there is a need to generate alternative energy, from renewable natural resources, to the point of meeting the needs of society, with minimal environmental impact.

Energy crops have been environmentally more sustainable alternatives to the intensive use of fossil fuels because the biomass produced can be used in several energy segments, for example, biofuel, electric energy and thermal energy. In the greenhouse gas (GHG) mitigation plan, these plants stand out from the fossil fuels for not emitting oxides to the environment responsible for the acid rains [1], low cost of production with minimal use of fossil fuel sources, high potential for carbon sequestration, once the emitted CO_2 is absorbed again during photosynthesis [2]. These characteristics have resulted in interest from both the private and public sectors, not only because of its economic applicability but also mainly because of the goals and agreements stipulated in the Rio 21, Kyoto Protocol and Paris Agreement [3].

There are promising species for energy use in the agricultural sector, among them elephant grass (*Pennisetum purpureum* Schum.), one of the most widespread tropical forage species in the world, used on livestock properties as a roughage [4]. Included among energy crops, it can be the most important renewable source for future energy production [5], due to its versatility such as fiber for paper industry [6]; biomass for the production of bioethanol [7]; direct combustion of biomass as a substitute for charcoal [8;9]; co-products generated in biorefineries [10;2]. In addition, it presents excellent energy balance elucidated by [11] in the use of in-kind burning of elephant grass, obtaining 21.3 units of renewable energy for each unit of fossil energy used in the production process.

In Brazil, Traditionally, eucalyptus and its co-products are widely used as an energy resource. In this sense, elephant grass appears as an option because it presents dry matter yields above 50 ton ha^{-1} year^{-1} [12], approximately double the eucalyptus; lower production cycle with semiannual harvest; C4 metabolism that ensures greater carbon assimilation; calorific power

between 4,100 and 4,500 kcal kg⁻¹ [13]; low production cost and the possibility of producing briquettes and pellets [14].

The variability of elephant grass genotypes is large and well under subtropical and tropical conditions in Brazil. Recently Embrapa released to the Atlantic Forest biome, the cultivar BRS Capiaçu to forage purposes [15], but with potential to energy production, it has produced more than 80 ton ha⁻¹ year⁻¹ with two semiannual harvests [16]. On the other hand, there are cultivars that are in disuse and can be promising for direct burning, due to the high contents of dry matter and fiber that present [17].

Since the elephant grass is among the most relevant crops as a renewable source for energy production in the coming decades, this study aimed to evaluate the agronomic characteristics of elephant grass genotypes on the energy production in the combustion form.

2. MATERIAL AND METHODS

The experiment was carried out at the Experimental Field of the *Empresa Mato-grossense de Pesquisa, Assistência e Extensão Rural* (EMPAER) in Cáceres – MT, Brazil, located at 16º09 "04" of Latitude South; 57º38 "03" West Longitude; altitude of 157 m. The climate in the municipality, according to the Köppen classification, is Aw type, that is, tropical, metamérmico climate, characterized by two well defined periods: dry (May to September) and rainy (October to April).

The experiment lasted two years (from 2016 to 2018), with harvests every 6 months counted after the standardization harvest (March 2016), being made one harvest in the dry season (September) and another one in the rainy season (March), in four harvests in two consecutive years.

Chemical and granulometric analysis of the soil of experimental area was carried out as shown in Table 1 prior to planting where the establishment fertilization recommendation was made. After the last harvest of the elephant grass, a new analysis of the soil was made to verify the level of fertility of the soil after the four harvest cycles. The soil was characterized as Chernosolic Eutrophic Red-Yellow ARGISSOLO, medium/clayey texture.

Table 1: Chemical and granulometric analysis in the 0 to 20 cm layer of the experimental area before planting (A) and after the last cut of the elephant grass (B).

	pH (CaCl₂)	P (mg dm⁻³)	K	Ca	Mg	Al	H+Al	SB	CEC	V (%)	OM (g dm⁻³)	SAND	SILT	CLAY
			(cmol$_c$ dm⁻³)									(g kg⁻¹)		
A	5.6	6.90	0.12	2.2	0.8	0.0	2.1	3.1	5.2	60	27.0	723	56	221
B	5.8	4.10	0.09	3.3	1.2	0.0	2.1	4.7	6.8	69	24.1			

P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; Al = Aluminium; H = Hydrogen; SB = Sum of bases; CEC = Cation exchange capacity; V = Base saturation; OM = Organic matter.

Soil preparation was done with a plowing and two harrowing in the month of September 2015, without application of limestone, due to the percentage of saturation per desired base being above 50%, considered adequate for establishment of elephant grass [18]. The elephant grass seedlings were obtained in the nursery of the Experimental Field of the EMPAER. The planting of the stems was done in a "foot-with-tip" system, with the seedlings placed in the planting groove and covered with soil, using a spacing of 1.0 m between rows.

The single fertilization was carried out in the establishment of elephant grass in the amounts of 70 kg of P_2O_5 ha⁻¹, 100 kg of K_2O ha⁻¹ and 100 kg of N ha⁻¹ using the following fertilizers: simple superphosphate, potassium chloride and ammonium sulfate, respectively. Both nitrogen and potassium fertilizer were divided in two applications, the first one in planting (November 2015), and the second one shortly after the harvest to uniformity (March 2016).

The experimental design was a randomized block with three repetitions. The treatments were arranged in subdivided plots scheme, considering as genotypes (Cubano Pinda, Porto Rico, Vrukwona, Piracicaba 241, Cuba 116, Taiwan A 25, Mercker, Napier, Canará, Guaçu, Cameroon and the CNPGL 93-41-1 and CNPGL 91-25-1 clones) and harvest season (dry and

rainy) as subplots. The experimental unit consisted of four rows of 5.0 m in length with spacing between rows of 1.0 m, totaling 20 m^2. The two central rows were considered as useful area, scoring 1.0 m at the ends.

The first harvest was made in September 2016 (drought harvest), and successive harvests were carried out every 6 months, as follows: March 2017 (rainy harvest), September 2017 (drought harvest); March 2018 (rainy harvest).
The agronomic characteristics evaluated were obtained by the arithmetic mean of three tillers selected at random within the useful area. They were: plant height – H (m), stem diameter – SD (mm), leaf length – LL (m), leaf blade width – LBW (cm), tillers number per linear meter – TN (linear m), dry matter yield per season – DMY (ton ha^{-1}) and annual dry matter yield – ADMY (ton ha^{-1}).

The dry matter content – DM% and stem percentage – SP% were obtained from three tillers selected at random within the useful area and represented the whole plant, leaf blade and pseudostem. These portions were duly separated into the morphological components, then minced and packed in a paper bag, weighed and placed in an oven of 55 ° C until reaching a constant mass. Afterwards, the samples were again weighed to obtain the air-dried sample.
The data collected were submitted to Lilliefors test for normality and Bartlett's test for homogeneity of variances. We proceeded with analysis of variance and Scott-Knott's test [19].

3. RESULTS AND DISCUSSION

3.1. Plant height, leaf length, leaf blade width and stem percentage

In the first year of cultivation, comparing both seasons (rainy and dry), all genotypes had higher H ($P < .05$) in the rainy. However, the CNPGL 93-41-1 clone did not differ statistically from the dry season (Table 2), which shows that the moisture factor did not affect it with a decrease in H. The H of genotypes in the dry season, there was no difference ($P > .05$) with an average of 2.56 m. Otherwise, the genotypes Cameroon, Porto Rico, Taiwan A 25, Vrukwona, Guaçu, Cuba 116, BRS Canará and Cubano Pinda had the highest H ($P < .05$) in the rainy season.

Table 2: Plant height (H), leaf length (LL), leaf blade width (LBW) and stem percentage (SP) of elephant grass genotypes, at 6 months of age in the dry and rainy seasons of the first year of cultivation (2016-2017).

Genotype	H (m)		LL (m)		LBW (cm)		SP (%)	
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
CNPGL 93-41-1	2.93aA	2.79bA	1.33aA	1.01aA	5.37aA	4.67aB	60.61aA	68.48aA
CNPGL 91-25-1	2.41aB	2.94bA	1.31aA	1.16aA	4.70bA	4.35bA	64.98aA	69.06aA
Taiwan A25	2.72aB	3.35aA	0.78bA	0.83aA	1.23eB	3.06cA	63.90aA	66.30aA
Cuba 116	2.67aB	3.41aA	1.11aA	0.88aA	3.74bA	3.08cA	70.56aA	66.70aA
Mercker	2.39aB	3.11bA	1.27aA	1.01aA	5.07aA	5.09aA	66.25aA	65.00aA
Cameroon	2.47aB	3.30aA	1.20aA	1.07aA	4.37bA	4.58aA	66.48aA	62.63aA
Piracicaba 241	2.26aB	3.11bA	1.38aA	1.04aB	5.03aA	3.99bB	72.62aA	66.13aA
Vrukwona	2.24aB	3.36aA	1.24aA	0.92aA	4.13bA	4.08bA	69.92aA	65.50aA
Napier	2.50aB	3.02bA	1.22aA	0.96aA	3.93bA	3.69cA	71.60aA	70.80aA
Porto Rico	2.67aB	3.35aA	0.73bA	0.99aA	2.30dB	3.12cA	70.17aA	63.20aA
Guaçu	2.85aB	3.38aA	1.09aA	0.95aA	3.17cB	4.02bA	75.07aA	69.70aA
Cubano Pinda	2.58aB	3.57aA	1.08aA	1.04aA	3.60bB	4.33bA	72.48aA	70.26aA
BRS Canará	2.55aB	3.47aA	1.35aA	1.01aB	3.77bA	4.14bA	75.39aA	70.80aA
CV (a) (%)	10.40		15.58		11.78		9.15	
CV (b) (%)	8.80		17.77		10.04		11.62	

CV (a) (%): Coefficient of variation of plot; CV (b) (%): Coefficient of variation of the subplot.

Averages followed by the same letter, lowercase vertical and uppercase horizontal do not differ from each other by the Scott Knott test at 5%.

In the second year of cultivation, CNPGL 93-41-1 presented a similar result to the other genotypes, obtaining greater H in the rainy season (Table 3). The H reduction in the dry season is due to the lack of rainfall, which restricts plant growth, occurring naturally at this time of year. With the return of rainfall, plant height increases were observed for all genotypes, thus demonstrating the direct relationship between soil water availability and elephant grass height [20].

The genotypes that presented, at the same time, greater H (P < .05) in the dry and rainy seasons in the 2nd year of cultivation were Taiwan A-25, Piracicaba 241, Cubano Pinda and BRS Canará with heights between 3.79 and 4.24 m. [16] evaluating semiannual harvests in elephant grass genotypes (BRS Capiaçu, Venezuela and Madeira), biomass sorghum (BRS 716) and sugarcane (RB 92579 and cane energy) verified plant height varying from 2.9 to 3.4 m among the evaluated species/cultivars, with emphasis on elephant grass that presented the superior heights. It is worth noting that elephant grass has the potential to reach more than 5.0 m in height, which makes this feature extremely important for energetic purpose of elephant grass, as it positively correlates with dry matter yield [21].

Table 3: Plant height (H), leaf length (LL), leaf blade width (LBW) and stem percentage (SP) of elephant grass genotypes, at 6 months of age in the dry and rainy seasons of the first year of cultivation (2017-2018).

Genotype	H (m)		LL (m)		LBW (cm)		SP (%)	
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
CNPGL 93-41-1	1.47bB	2.58cA	0.87aA	0.99aA	4.07aA	4.90aA	56.97aA	69.39aA
CNPGL 91-25-1	1.55bB	3.95aA	0.79aA	0.22cB	3.82aA	1.67bB	63.89aA	74.09Aa
Taiwan A25	1.84aB	4.31aA	0.75aA	0.22cB	1.59bA	1.17bA	73.52aA	68.72aA
Cuba 116	1.91aB	3.50bA	0.75aA	0.54bA	3.21aA	2.50bA	69.46aA	77.10aA
Mercker	1.52bB	3.47bA	0.83aA	0.63bA	4.09aA	3.87aA	58.29aA	73.75aA
Cameroon	1.88aB	3.48bA	0.87aA	0.93aA	3.88aA	4.23aA	70.53aA	77.08aA
Piracicaba 241	1.88aB	3.79aA	0.82aA	0.40cB	3.20aA	3.30aA	66.96aA	64.01aA
Vrukwona	2.01aB	3.27bA	0.78aA	0.70bA	3.54aA	3.90aA	69.60aA	68.08aA
Napier	1.52bB	3.04bA	0.81aA	0.92aA	3.02aA	3.50aA	60.96aA	46.17aA
Porto Rico	2.11aB	3.36bA	0.84aA	0.67bA	1.71bA	2.67bA	67.49aA	54.39aA
Guaçu	2.15aB	3.27bA	0.74aA	0.64bA	2.13bA	3.00aA	74.79aA	63.48aA
Cubano Pinda	1.96aB	4.12aA	0.85aA	0.25cB	2.13bA	1.67bA	73.45aA	73.61aA
BRS Canará	2.06aB	4.24aA	0.84aA	0.29cB	3.04aA	1.90bA	67.13aA	67.56aA
CV (a) (%)	18.12		21.96		25.01		13.72	
CV (b) (%)	11.35		24.38		24.62		15.16	

CV (a) (%): Coefficient of variation of plot; CV (b) (%): Coefficient of variation of the subplot. Averages followed by the same letter, lowercase vertical and uppercase horizontal do not differ from each other by the Scott Knott test at 5%.

In the first year of cultivation, comparing the two seasons, all genotypes presented lower LL in the dry season (P < .05), except for Piracicaba 241 and BRS Canará genotypes (Table 2). During the dry season, there was a significant difference between the genotypes (P < .05) where only Porto Rico and Taiwan A 25 had lower LL, respectively, with 0.73 and 0.78 m. There was no significant difference between genotypes in the rainy season, with average LL of 1.07 m.

In the second year of cultivation, there was a statistical difference between both seasons, being that the CNPGL 91-25-1, Taiwan A 25, Piracicaba 241, Cubano Pinda and BRS Canará genotpes had the lowest LL in the rainy season (P < .05) (Table 3). In the dry season, there was no difference between genotypes, with average LL of 0.81 m.

The leaf blade is responsible for the photosynthesis and fixation of free carbon in the plant structure, but this can change the chemical characteristics of the biomass because there is a higher deposition of minerals compared to the more fibrous fraction coming from the stem [22]. This is undesirable due to the formation of chemical compounds that at high temperature damage the metallic surfaces of the boilers and increase the deposition of ashes [23].

As a strategy for the reduction of post-burning residues and better quality of biomass, the productive cycle of the energy crop is very important because gains are obtained as increased dry matter yield and percentage of fibers and reduction of minerals. [24], evaluating the yield of elephant grass BRS Canará to hay production at harvest intervals of 42, 60, 76, 91 and 105 days in the rainy season, verified an increase in dry matter yield and reduction in mineral matter, according to the increase in age, which consequently will have a direct influence on the calorific value of the biomass.

To LBW in the first year of cultivation, comparing both seasons, all genotypes had higher LBW in the rainy season (P < .05), except for CNPGL 93-41-1 and Piracicaba 241 genotypes which obtained respectively 4.67 and 3.99 cm (Table 2). When observed within each season, the CNPGL 93-41-1 clone and the Mercker genotype obtained higher LBW within the dry season near to Piracicaba 241, as in the rainy season, near to the Cameron.

In the 2nd year of cultivation, comparing the seasons, just CNPGL 91-25-1 genotype presented superior LBW (P < .05) in the dry season than the others (Table 3). In the dry season, there was a significant difference with superior LBW for most genotypes (P < .05), excepting Taiwan A 25, Porto Rico, Guaçu, Cubano Pinda with respective values of 1.59; 1.71; 2.13; 2.13 cm. In the rainy seasons the superior LBW (P < .05) was obtained by CNPGL 93-41-1, Mercker, Cameroon, Piracicaba 241, Vrucwona, Napier and Guaçu genotypes.

In breeding programs for biomass production, genotypes with higher LBW have a negative correlation with dry matter production (r=-0.81), in contrast, increases in variables such as H, SD and TN, the lower the LBW and thus higher DMY values will be obtained, according to [21]. Decrease in DM yield of elephant grass due to the presence of leaf blade is probably due to the lower density of this fraction, especially when compared with the stem. "Lighter" morphological structures are undesirable in direct burning due to the correlations between their elemental components (carbon, hydrogen, oxygen) and the quality of thermal energy [25]. In addition, the stem/leaf ratio has a direct influence on the biomass calorific value, which is generally higher in the stems [8]. Therefore, genotypes with lower leaf area (length and width) can present biomass with better quality of burning.

To SP there was no significant difference (P > .05) between seasons and genotypes, independent of the years of cultivation, and the average obtained was 68.21% and 67.21% to the first and second year of cultivation, respectively (Tables 2 and 3). [28], studying agronomic traits and elephantgrass biomass from nitrogen doses, also did not find differences (P> .05) between the genotypes and the doses studied, and SP ranged from 60 to 70%.

The high stem percentage in elephant grass results in a higher stem/leaf ratio, and this reflects directly on biomass quality. [8], when making the characterization of the different parts of the elephant grass to the production of biofuels, verified a difference between the stem and leaf blade fraction, being ashes 1.75 and 4.0%, respectively; calorific power 18.11 and 16.21 MJkg^{-1}; nitrogen 0.99 and 1.01%; sulfur 1.47 and 1.75%. The stem of the elephant grass is structured in a fibrous, harder part, which forms the bark and marrow with vascular bundles rich in fibers. Its morphological structure is similar to sugarcane bagasse [26], which is already widely used as a source of energy in the form of combustion in the sugar and alcohol industry.

3.2 Stem diameter, tillers number, dry matter yield and annual dry matter yield

According to [27; 28] the SD is of great importance in the selection of genotypes, since it is directly related to the dry matter yield besides biomass quality. Higher SD results in higher content of lignocellulosic compounds in the cell wall. Thus, the reduction in the volatile fractions of the biomass as the hemicellulose, polysaccharides of lesser relevance in the composition of the oxidizer compared to the other fibrous fractions such as lignin and cellulose, due to the low thermal stability and the lower activation energy in the direct combustion. In addition, its presence increases ash generation during combustion [29;30].

When comparing the two seasons in the first year, the genotypes had no difference (P > .05), excepting CNPGL 91-25-1 and Piracicaba 241 which showed a reduction in the SD during the rainy season (P < .05) with values of 15.08 and 13.30 mm, inversely to Cuba 116 in the dry season (P < .05) with 13.0 mm (Table 4). In the dry season, the CNPGL 93-41-1, Piracicaba 241, CNPGL 91-25-1 and Mercker genotypes, were highlighted with higher SD (P < .05). In the rainy season, only Cubano Pinda presented the largest SD (P < .05) with 20.58 mm.

Table 4: Annual dry matter yield (ADMY) and by season (DMY), stem diameter (SD) and tillers number (TN) of elephant grass genotypes at 6 months of age in the dry and rainy seasons of the first year of cultivation (2016-2017).

Genotype	SD (mm)		TN (linear m)		DMY (ton ha^{-1})		ADMY (ton ha^{-1} year^{-1})
	Dry	Rainy	Dry	Rainy	Dry	Rainy	
CNPGL 93-41-1	17.33aA	16.08bA	14.61bA	14.11aA	16.71aA	22.81bA	39.52b
CNPGL 91-25-1	18.33aA	15.08bB	18.67bA	20.00aA	25.98A	31.43aA	57.41a
Taiwan A25	12.00bA	14.25bA	22.94aA	19.00aA	16.87aA	24.30bA	41.18b
Cuba 116	13.00bB	16.42bA	17.72bA	20.33aA	15.57aB	31.72aA	47.30b
Mercker	16.67aA	16.08bA	16.83bA	16.17aA	25.79aA	32.48aA	58.27a
Cameroon	15.00bA	16.50bA	17.22bA	18.06aA	22.19aA	25.68bA	47.87b
Piracicaba 241	17.67aA	13.30bB	14.78bA	14.22aA	16.91aA	23.28bA	40.20b
Vrukwona	14.00bA	14.17bA	18.78bA	16.83aA	19.48aA	26.82bA	46.30b
Napier	14.00bA	15.00bA	20.11bA	17.11aA	24.50aA	21.64bA	46.14b
Porto Rico	14.67bA	13.17bA	26.72aA	20.94aA	22.50aB	34.26aA	58.76a
Guaçu	13.33bA	15.33bA	18.72bA	15.72aA	17.89aA	25.98bA	43.88b
Cubano Pinda	13.00bB	20.58aA	17.72bA	14.50aA	18.82aB	33.32aA	52.15a
BRS Canará	13.00bA	14.83bA	18.17bA	16.33aA	24.79aA	34.78aA	59.58a
CV (a) (%)	12.39		25.48		30.61		26.89
CV (b) (%)	11.09		19.34		24.58		16.33

CV (a) (%): Coefficient of variation of plot; CV (b) (%): Coefficient of variation of the subplot. Averages followed by the same letter, lowercase vertical and uppercase horizontal do not differ from each other by the Scott Knott test at 5%.

In the second year of cultivation, comparing both seasons, it is verified that in the rainy season there was a greater SD (P < .05) to the CNPGL 93-41-1, CNPGL 91-25-1, Taiwan A 25, Napier, Porto Rico and Cubano Pinda genotypes (Table 5). In the rainy season, the CNPGL 93-41-1, CNPGL 91-25-1 and Cubano Pinda genotypes had the largest SD. There was no difference (P < .05) between the genotypes during the dry season and the mean was 13.61 mm.

Table 5: Annual dry matter yield (ADMY) and by season (DMY), stem diameter (SD) and tillers number (TN) of elephant grass genotypes at 6 months of age in the dry and rainy seasons of the first year of cultivation (2017-2018).

Genotype	SD (mm)		TN (linear m)		DMY (ton ha^{-1})		ADMY (ton ha^{-1} year^{-1})
	Dry	Rainy	Dry	Rainy	Dry	Rainy	
CNPGL 93-41-1	15.56aB	22.33aA	19.61cA	16.83bA	13.08aA	15.19aA	28.28a
CNPGL 91-25-1	14.22aB	21.33aA	20.56bA	18.94aA	14.39aA	14.65aA	29.04a
Taiwan A25	9.67aB	14.33bA	26.67aA	21.44aB	12.26aA	10.64aA	22.90a
Cuba 116	14.78aA	17.00bA	21.06bA	21.33aA	13.33aA	16.15aA	29.48a
Mercker	15.67aA	16.33bA	15.56dA	15.39bA	16.86aA	20.31aA	37.18a

Cameroon	15.22aA	17.33bA	21.44bA	9.56bB	18.38aA	13.47aA	31.85a
Piracicaba 241	13.78aA	17.00bA	13.44dA	16.17bA	14.37aA	13.62aA	27.99a
Vrukwona	14.33aA	16.00bA	18.50cA	12.44bB	16.00aA	16.38aA	32.38a
Napier	12.89aB	17.00bA	21.39bA	13.50bB	14.63aA	12.15aA	26.79a
Porto Rico	11.78aB	17.67bA	25.22aA	25.28aA	11.97aA	16.73aA	28.71a
Guaçu	12.78aA	15.67bA	18.94cA	13.44bB	13.13aA	15.58aA	28.71a
Cubano Pinda	12.56aB	20.33aA	18.56cA	12.39bB	12.27aA	16.48aA	28.75a
BRS Canará	13.67aA	16.00bA	17.39cA	13.56bA	16.79aA	19.69aA	37.18a
CV (a) (%)	15.07		27.06		30.21		26.89
CV (b) (%)	12.76		13.69		28.50		16.33

CV (a) (%): Coefficient of variation of plot; CV (b) (%): Coefficient of variation of the subplot. Averages followed by the same letter, lowercase vertical and uppercase horizontal do not differ from each other by the Scott Knott test at 5%.

The tillering is a characteristic of high heritability and interest in breeding programs, since the possibility of crossing [31], because it can contribute to obtain genotypes with higher dry matter yield [21]. When comparing both seasons in the first year of cultivation, there was no significant difference between the genotypes (Table 4). The Taiwan A 25 and Porto Rico genotypes had higher TN in the dry season (P < .05), with 22.94 and 26.72 tiller linear m^{-1}, respectively.

In the rainy season, there was no statistical difference between genotypes with a mean of 16.17 tiller linear m^{-1}. [32] observed higher TN, evaluating 80 elephant grass genotypes at different times. These authors contacted that TN varied between 22 and 91 for the genotypes Cana D'África and BAG-92, respectively, in the dry season, and from 26.1 to 72.6 tiller linear m^{-1} to genotypes Goiano and EMPASC 309 respectively, in the rainy season.

In the second year of cultivation, when comparing both seasons, the Taiwan A 25, Cameroon, Vrukwona, Napier, Guaçu and Cubano Pinda genotypes obtained higher TN (P < .05) in the dry season (Table 5). In the dry season, the best genotypes were Taiwan A 25 and Porto Rico with TN of 26.67 and 25.22, respectively. In the rainy season, the genotypes that presented higher NT (P < .05) were CNPGL91-25-1, Taiwan A25, Cuba 116 and Porto Rico with values ranging from 25.88 to 18.94 tiller linear m^{-1}.

However, it does not mean that genotypes that produce a high number of tillers will result in high dry matter yield for energy production via direct combustion. This variable is most useful to predict the potential of dry matter production [33]. According to [34], there are two canonical pairs with distinct slopes in the elephant grass, that is, when the plant grows more, it becomes smaller and with a smaller diameter. This results in plants with low fiber content and high nitrogen content culminating in low calorific power. Another aspect is that when the plant has less, its stems are more robust and the plants are higher, with high fiber contents, low nitrogen content and consequently high calorific value.

Comparing dry matter yield in the first year of cultivation between both seasons (Table 4), observed lower DMY to Cuba 116, Porto Rico and Cubano Pinda genotypes in the dry season. This may be a problem and indicate that these genotypes have low genotypic stability over the two seasons. In addition, they can interfere in the planning of the activities of a company that produces ecological firewood that will have a reduction in the production during the dry period.

During the dry season, there was no difference between the genotypes and the mean DMY was 20.38 ton DM ha^{-1}. Otherwise, in the rainy season, the genotypes that obtained the highest DMY (P < .05) were CNPGL 91-25-1, Cuba 116, Mercker, Porto Rico, Cubano Pinda and BRS Canará. It can be noticed that only in the cut of the waters, these genotypes showed yield above 30 ton DM ha^{-1} harvest^{-1}, that is, values above the yield obtained by eucalyptus (20 ton DM ha^{-1} year^{-1}).

Regarding annual dry matter yield in the first year of cultivation (Table 4), there are promising genotypes with yield above 50 ton DM ha^{-1} year^{-1}. The BRS Canará, Porto Rico, Mercker, CNPGL 91-25-1 and Cubano Pinda genotypes were the ones that stood out the most with ADMY ranging from 52.15 to 59.58 ton DM ha^{-1} year^{-1}. Regarding to BRS Canará genotype, this was launched in 2012 by Embrapa to be used in the form of grass, with the harvest and supply in the form of forage to the animals, but we can see the double suitability of this genotype and can also be used for bioenergy production.

Genotype yield demonstrates why elephant grass stands out among energy crops [35], and with total possibility of insertion into the Brazilian energy matrix consolidated by the use of sugarcane and eucalyptus, mainly by the amount of biomass produced and the production cycle [2]. [12], evaluating elephant grass cultivars in the Northeast region of Brazil, observed that BRS Canará and Cubano Pinda obtained ADMY ranging from 66.3 to 84.3 ton DM ha^{-1} year^{-1} at 6 months of cultivation.

In the second year of cultivation (Table 5), there was no difference (P> .05) to seasons and genotypes within each season, with mean DMY of 14.94 ton DM ha^{-1} and mean ADMY of 29.94 ton MS ha^{-1} year^{-1}, that is, it occurred a 39.17% and 39.05% reduction, respectively. Nevertheless, it was verified that all the genotypes had dry matter yield higher than that obtained by eucalyptus (20 ton DM ha^{-1} year^{-1}).

The reduction in dry matter yield per season and annual obtained in the second year of cultivation was due to reduction of soil fertility and not replacement of nutrients through fertilization, since after the last harvest, the reduction in nutrient contents P, K and OM (Table 2). A similar occurrence was verified by [36], because the mean DMY of eight elephant grass genotypes was 17.5 ton DM ha^{-1} year^{-1} (2012 and 2013), but decreased 6.4 ton DMM ha^{-1} (2013 and 2014), which was expected due to the reduction of natural soil fertility.

Elephant grass is naturally a grassland with high productive potential, either to animal feed or to energetic purposes, but the crop presents high extraction of nutrients from the soil, such as N, K, Ca and S, [37]. According [38], evaluating the nutrient removal in elephant grass pasture, observed that the yield of 30 ton DM ha^{-1} year^{-1} provides extraction equivalent to 480 kg N ha^{-1} year^{-1}, 361 kg K$_2$O ha year^{-1} and 117 kg P$_2$O$_5$ ha^{-1} year^{-1}. [39], evaluating elephant grass genotypes for energy production in the form of biomass, verified that the most extracted nutrients of the soil were potassium (310 kg ha^{-1}), calcium (167 kg ha^{-1}), nitrogen (121 kg ha^{-1}), magnesium (79 kg ha^{-1}) and phosphorus (41.4 kg ha^{-1}), which are essential to better exploit the productive potential of the crop.

Thus, the economic exploitation of elephant grass for bioenergy production via direct combustion special attention should be given to the replacement of nutrients, in order to maintain or even increase the dry matter yield obtained in the first year, in the following years that are want to produce.

4. CONCLUSION

Elephant grass is an excellent alternative for energy purposes mainly due to high percentage of stem and dry matter yield, but maintenance of soil fertility is necessary to obtain satisfactory yields.

According to the agronomic characteristics, the promising genotypes for direct burning are CNPGL 91-25-1, Cubano Pinda, BRS Canará, Porto Rico and Mercker.

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