DEVELOPMENT AND SELECTION OF ELEPHANT GRASS GENOTYPES FOR ENERGY BIOMASS PRODUCTION

ABSTRACT

The purpose of this research was to evaluate the behavior *per se* of elephant grass (*Pennisetum purpureum* Shum) hybrids for energy purposes by means of morpho-agronomic traits in four evaluation sections. An experiment in randomized block design with three replicates was applied to evaluate the hybrids. The plot consisted of a 15-m row with 1.50-m row spacing, and 1.50-m spacing between plants. The usable area was composed of the five central plants. It was evaluated Number of tillers per clump; Stem diameter; Plant height; Plant dry matter yield; and Percentage of dry matter. Computational resources from the GENES Program were used to analyze the results. For both cuts, most of the traits evaluated, with the exception of percentage of dry matter and stem diameter, expressed significant values for the genotypes, suggesting the existence of genetic variability. For higher biomass yields, H7, H11, and H14 hybrids should be selected.

Keywords: bioenergy, genetic breeding, *Pennisetum purpureum* Shum.

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1. INTRODUCTION

In recent years, there has been a growing demand for energy as a result of the indiscriminate use of fossil fuels and the resulting increase in pollution and carbon emissions into the atmosphere. In this regard, projects with a focus on fossil energy generation may have significant and irreversible environmental impacts. Because of this, new studies have been conducted in order to create alternative energy sources [1].

Bioenergy is the energy obtained by converting biomass, being a form of renewable energy [2]. In view of this, biomass is a promising resource for energy production, presenting economic and environmental advantages with significant relevance because of its low production cost, in addition to reducing carbon dioxide (CO_2) emissions, with the possibility of being converted into chemical products, thermal/electric energy, biofuels, or other essential materials [3].

Elephant grass (*Pennisetum purpureum* Schum.) is one of the most important species used for this end, since it has a high yield in comparison with eucalyptus and sugarcane, producing approximately 40 tons of dry matter per hectare per year [4]. This production occurs according to its photosynthetic efficiency, attributed to its C4 metabolism [5]. This forage also shows characteristics such as high fiber content, high C/N ratio, and high calorific value [6,7].

Studying yield traits in elephant grass with the aim at increasing crop yield is of major importance for the success of breeding programs [8]. Considering that hybridization is one of the best strategies to obtain superior individuals, it is possible to achieve hybrids of elephant grass with superior yield performance to that of their genitors [9].

Considering this, the scope of this study was to determine the performance *per se* of elephant grass hybrids obtained for energy purposes.

2. MATERIAL AND METHODS

The experiment was conducted in an experimental area of the *Universidade Estadual do Norte Fluminense Darcy Ribeiro* (UENF), located at the State Center for Research in Agroenergy and Waste Utilization (*Centro Estadual de Pesquisas em Agroenergia e Aproveitamento de Resíduos*–CEPEAA) of the PESAGRO-RIO Experimental Station, in the municipality of Campos dos Goytacazes, Rio de Janeiro State, Brazil, at 21°44'47'' S, 41°18'24'' W, and 11 m altitude. The soil of the experimental area consists of a flat topography, classified as Argisol, dystrophic.

Meteorological data were collected from the automatic agrometeorological station near the experimental area. Figure 1 depicts monthly rainfall and temperature values referring to the period of the experiment (November 2014 to March 2017).

The climate of the North Region of Rio de Janeiro State is, according to the Köppen classification system [10], Aw-type, tropical hot and humid, with a dry period in winter and rainy in summer, with an annual rainfall of around 1,153 mm [11]. During the evaluation period, rainfall was much lower than the climatological normal, and the average for the years 2014 to 2017 was 659.75 mm.

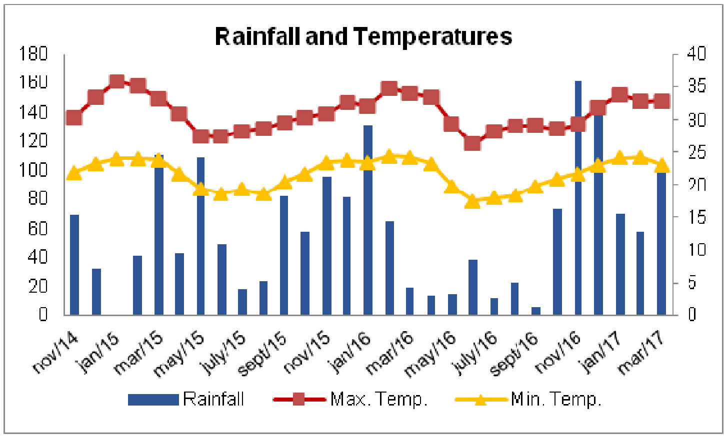

Figure 1. Rainfall and maximum and minimum temperatures during the elephant grass experiment. Municipality of Campos dos Goytacazes, Rio de Janeiro State, 2014-2017.

A total of 15 hybrids from crosses between ten elephant grass genotypes were evaluated (Table 1), previously selected according to studies for biomass production, adding some traits, such as late flowering, dry matter yield, stem diameter, number of tillers [12].

Table 1. Identification of the ten genitors of elephant grass from the work collection of the Germplasm Bank of Elephant Grass of UENF, used in diallel crosses.

Genotype	Origin
Cubano Pinda	UFRRJ Seropédica
Vrukwona	CENARGEM
IAC-Campinas	UFRRJ Seropédica
Capim Cana D'África	IPEACS Linhares
Cameroon	ESALQ Piracicaba
CPAC	CENARGEM
IJ 7139	EPAGRE
União	-
Guaçu/I.Z.2	Nova Odessa
Cuba-115	Cuba

Soil preparation consisted of two plowing harrows. Transplanting of the seedlings into the field was performed on December 17, 2014. Supplementary irrigation by conventional sprinkler system was performed only in the planting and establishment of plants (first three months).

To evaluate the hybrids together with the genitors, a randomized block design with three replicates was used. The experimental unit consisted of a 15-m row with 1.50-m row spacing, and 1.50-m spacing between plants.

In conducting the experiment, fertilization was determined based on the results obtained in the soil analysis, which consisted of 714 kg ha^{-1} of the chemical formula 4-14-8 (NPK) divided into five periods: in planting, and one in each evaluation cut. The plant was cut close to the ground and weighed in the field. A fraction of each clump (three tillers) was taken to the laboratory for drying in a forced air oven at 65ºC for 72 hours, for subsequent determination of dry matter mass.

Cuts were made every six months in such a way that the 1st took place on 14 July 2015; the 2nd was made on 19 February 2016; the 3rd cut, on 2 September 2016; and the 4th, on 5 March 2017.

All evaluations were performed on five individual plants of each plot, and the following traits were measured:

- ✓ Number of tillers per clump - it was performed by counting the number of tillers per clump;
- ✓ Stem diameter - the stem diameters of three random tillers of each plot were measured around 20 cm from the ground, using a digital pachymeter;
- ✓ Plant height - measurements were taken from the base of the tiller to the inflection of the highest leaf using a tape measure expressed in meters;
- ✓ Plant dry matter yield - a sample was taken from each plot at random and each part chopped and packed in an identified paper bag, weighed and placed in an oven at 65 ℃ for 72 hours. The samples were then weighed again to obtain the air-dry sample (ADS), following the methodology described by Silva and Queiroz [13].
- ✓ Percentage of dry matter - the dry matter was ground in a Wiley mill with a 1-mm sieve and packed in plastic bags for the determination of the sample dried in an oven (ASE). For the determination of the ADS, 2 g of each ground material were kept in an oven at 105℃ for 12 hours and then weighed again, according to the methodology described by Silva and Queiroz [13].

Computational resources from the GENES Program were applied to examine the results [14].

On the basis of the traits measured in the five individual plants in the 15 hybrids, the mean of each plot was calculated, and an analysis of variance per cut was conducted, using the following genetic-statistical model:

$$Y_{ij} = \mu + g_i + b_j + \xi_{ij}$$

in which,

Y_{ij}: observed value of the i-th genotype in the j-th block

μ: general constant

g_i: effect of genotype i, (i=1, 2, 3,…, 25)

b_j: effect of block j, (j=1, 2, and 3) NID, $(0, \sigma^2_b)$

ξ_{ij}. experimental error associated with observation Yij NID, $(0, \sigma^2)$

3. RESULTS AND DISCUSSION

The result of the individual variance analysis for each cut of the morpho-agronomic traits evaluated in the 1st, 2nd, 3rd, and 4th evaluation cuts, including 15 hybrids resulting from diallel crosses, can be found in Table 2.

For the 1st evaluation cut, it was found there was significance (P<0.01) between genotypes for dry matter yield (DMY) and number of tillers (NT) traits. In the case of the percentage of dry matter trait, it was significant at 5% (P<0.05), in agreement with the Fisher F test. Height (HEI) and stem diameter (SD) traits did not exhibit significant differences (P<0.05).

The 2nd evaluation cut showed different results in comparison to the 1st one. There were no significant differences for all traits analyzed, except for the DMY trait, in which there was a significance of 1% (p<0.01). High biomass production capacity is one of the most significant traits to be considered in this crop[15], and the genetic variability in the population under evaluation enables the successful selection of promising genotypes, and, as a result, the collection of genetic gains in this population.

Table 2. Estimates of mean squares, means and coefficient of variation of five morpho-agronomic traits evaluated in elephant grass genotypes in the 1st evaluation cut. Campos dos Goytacazes, RJ, 2014-2017.

F.V.	GL	DMY	%DM	TP	HEI	SD
			Cut 1			
Block	2	11,279	1,889	2,895	0,444	16,060
Hybrid	14	62,416**	3,953*	46,229**	0,052^{ns}	1,283^{ns}
Residue	28	8,994	1,706	14,747	0,045	1,393
Mean		18,28	28,09	21,91	3,53	15,23
CV(%)		16,41	4,65	17,53	6,06	7,75
			Cut 2			
Block	2	37,258	18,605	3,971	0,060	0,538
Hybrid	14	66,519**	3,288^{ns}	38,483^{ns}	0,033^{ns}	1,660^{ns}
Residue	28	5,879	3,585	26,785	0,021	1,145
Mean		19,24	33,03	21,99	2,71	15,58
CV(%)		12,6	5,73	23,53	5,39	6,87
			Cut 3			
Block	2	4,772	340,170	0,093	0,423	3,177
Hybrid	14	12,725**	21,683^{ns}	28,886**	0,241**	5,659^{ns}
Residue	28	1,804	110,785	5,115	0,039	3,185
Mean		3,34	37,02	11,58	1,99	12,1
CV(%)		40,18	28,43	19,53	9,93	14,75
			Cut 4			
Block	2	33,486	79,214	20,181	2,247	3,180
Hybrid	14	39,288 **	4,948^{ns}	49,002**	0,087^{ns}	3,829^{ns}
Residue	28	7,131	4,823	14,141	0,063	2,731
Mean		8,52	28,54	13,5	2,27	17,49
CV(%)		31,35	7,7	27,85	11,1	9,45

** and * significant at 1 and 5% probability, respectively, by the F test, ^{ns} non-significant by the F test.

Regarding results from the 3rd cut, there were significant differences, by the F test (P<0.01), for the variation source Treatment in all traits, but not for %DM trait (percentage of dry matter), which, similarly to the 2nd cut, did not have significant differences, and stem diameter (SD) trait, which did not present significant differences (P<0.05) in any of the evaluated cuts. The non-significant effect of genotypes suggests the population has no breeding potential for such a trait (%DM and SD), thereby corroborating the genetic variability between genotypes for the other traits examined (Table 2).

On the basis of the results, it was found that there were significant differences in the 4th cut for dry matter yield (DMY) and number of tillers (NP) traits by using the F test at (P<0.01). On the other hand, no significant differences were detected for the %DM, HEI, and SD traits, similar to what was observed in the 2nd evaluation cut.

Coefficients of experimental variation (CV%) of the morpho-agronomic traits generally showed lower values when evaluating the 1st and 2nd cuts: in the 1st cut, ranging from 4,65%, in the %DM trait, to 16,41%, in the DMY trait; in the 2nd cut, ranging from 5,39%, in the %DM trait, to 23,53% in the NT trait. For the 3rd cut, they ranged from 9,93%, for HEI, to 40,18%, and, for the 4th cut, from 7,7%, for %MS, to 31,35%, for PM. As such, findings frequently obtained in studies on this culture were validated [12; 16; 17].

These variations are indicative of the precision of the experiment; in agricultural experimentation, they can be considered low when they are less than 10%; medium when they range from 10% to 20%; high when they are between 20% and 30%; and very high when their value exceeds 30% [18].

In the 1st, 3rd, and 4th cuts, the highest coefficients of variation are relative to the dry matter yield (DMY) trait. This variation can be justified because the trait under study is of polygenic inheritance, thus highly influenced by the environment; consequently, these values are acceptable [19].

With the aim of obtaining hybrids with biomass production capacity, it can be seen that the genotypes revealed a high average of dry matter yield. Results found herein confirm the findings of [7], which, by evaluating yield traits and biomass quality of six elephant grass genotypes under five different production ages, in Campos dos Goytacazes, obtained dry matter yield of 19,11 t. ha^{-1} at 6 months.

On the basis of the treatment means, there was no discrepancy between the 1st and 2nd cut means. For the 3rd evaluation cut, means found were lower in comparison to the 1st and 2nd cuts. Such a reduction correlates with climatic conditions in the growing months, as shown in Figure 1, in which it can be seen that the period between March and September 2016 was the one with the lowest precipitation, which led to a decrease in productivity in this cut. By evaluating the elephant grass genotypes, Sousa et al. [20], also verified an influence of the environmental conditions (temperature, brightness, rainfall distribution) on the genotypes during the growing period of the crop.

The mean estimates of the dry matter yield trait (DMY) evaluated in 15 hybrids resulting from circular diallel crosses, in four cuts, by the Scott-Knott test of mean comparison at 5% probability, are depicted in Table 3.

The hybrid that stood out the most in the analysis of mean values referring to the DMY trait, in the 1st, 2nd, 3rd, and 4th evaluation cuts, was the H11 (Capim Cana D'Africa x Guaçu/I.Z.2), with a total yield of 21,719 t. ha^{-1}, adding the four evaluation cuts. Regarding the individual cuts, hybrid H11 displayed a total yield of 30.305 t. ha^{-1} in the 1st cut; 31,347 t. ha^{-1} in the 2nd cut; and 17,282 t. ha^{-1} in the 4th cut of evaluation. Regarding the 3rd cut, four hybrids presented better performance than the others, namely H7 (IAC-Campinas x IJ 7139), H11 (Capim Cana D'África x Guaçu/I.Z.2), H14 (Cameroon x Cuba-115), and H15 (CPAC x Cuba-115) hybrids.

Table 3. Mean values for the dry matter yield (DMY) trait of the four evaluation cuts in 15 hybrids resulting from circular diallel crosses following the Scott-Knott test at 5% probability. Campos dos Goytacazes, RJ, 2014-2017.

Genotype	Dry Matter Yield (t/ha^{-1})				
	Cut 1	Cut 2	Cut 3	Cut 4	Mean
H1	14,298c	18,003c	1,602b	5,519c	9,855c
H2	15,808c	14,315c	2,653b	5,881c	9,664c
H3	17,880c	16,727c	2,202b	5,724c	10,633c
H4	15,204c	17,438c	2,698b	6,022c	10,340c
H5	18,518c	18,198c	1,568b	6,508c	11,197c
H6	13,607c	16,081c	1,626b	5,408c	9,180c
H7	20,917c	23,822b	6,184a	12,300b	15,805b
H8	15,884c	19,129c	2,302b	5,316c	10,657c
H9	16,706c	16,770c	1,771b	6,578c	10,456c
H10	17,707c	13,224c	2,048b	8,176c	10,288c
H11	30,305a	31,347a	7,945a	17,282a	21,719a
H12	13,167c	15,570c	2,049b	7,858c	9,660c
H13	20,587c	22,859b	4,038b	11,497b	14,745b
H14	25,075b	20,903c	5,893a	10,692b	15,640b
H15	18,496c	24,219b	5,563a	13,030b	15,327b
Mean	18,277	19,240	3,343	8,519	12,344

* Means followed by the same letter do not differ statistically from each other, in the column, by the Scott-Knott test at 5% of probability.

It was noted that the 1st and 2nd cuts had higher means when compared to the 3rd and 4th cuts. This difference was caused by low precipitation during the growing months of the 3rd cut; in the 4th cut, despite a better rainfall rate, the hybrids did not reach their maximum point of growth. This happened because many tillers were damaged by drought in the 3rd cut, not occurring their sprouting with the return of rainfall. As Corsi et al. [21], state, lack of water imposes limitations on the rate of leaf expansion, number of leaves per tiller, and number of tillers; consequently, this leads to a lower dry matter yield.

Considering the significant lack of rainfall during the second year of evaluation, the results obtained were quite positive. As stated by Menezes et al [9], in elephant grass hybrids, the highest dry matter yield found among hybrids was 19,76 t. ha^{-1} in water cut. Morais et al. [22], examined five genotypes for yield and found a higher mean yield of 23,6 t. ha^{-1} for the 'Gramafante' cultivar in a cut interval of nine months, which led to lower results than the ones found in this study. Flores et al. [23], on the other hand, investigating the performance of the Paraíso and Roxo genotypes for biomass production for energy purposes, in the edaphoclimatic conditions of the Cerrado, obtained a mean above 30 t. ha^{-1}.

Table 4 describes the mean estimates of percentage of dry matter (%MS) trait evaluated in 15 hybrids obtained from circular diallel crosses, in four cuts, by Scott-Knott grouping of mean comparison at 5% probability.

As it is possible to notice, there was the formation of two groups, with significant difference at the level of 5% probability ($P<0.05$) for the 1st evaluation cut, being the H1 (Cubano Pinda x Cameroon), H2 (Cubano Pinda x CPAC), H5 (Vrukwona x IJ 7139), H9 (IAC-Campinas x Guaçu/I.Z.2).), H10 (Capim Cana D'África x União), H11 (Capim Cana D'África x Guaçu/I.Z.2), and H13 (Cameroon x Guaçu/I.Z.2) hybrids the the most outstanding, with the highest percentage observed at 30,07% for the 11 hybrid (Capim Cana D'África x Guaçu/I.Z.2).

Regarding the 2nd, 3rd, and 4th cuts and total yield, no significant differences were observed between genotypes ($P<0.05$) (Table 7), with the highest percentage found being 34,70% for 7 hybrid (IAC-Campinas x IJ 7139), 40,65% for 8 hybrid (IAC-Campinas x União), and 31.56% for 11 hybrid (Capim Cana D'África x Guaçu/I.Z.2), in cuts 2, 3, and 4, respectively. The means found in this study confirm the ones found by Rossi et al., [12], and Vidal et al., [7], with percentages of dry matter of 37,16% and 36,08%, respectively.

Table 4. Mean values for the percentage of dry matter (%MS) trait of the four cuts of evaluation on 15 hybrids resulting from circular diallel crosses following the Scott-Knott test at 5% probability. Campos dos Goytacazes, RJ, 2014-2017.

Genotype	Percentage of Dry Matter (%)				
	Cut 1	Cut 2	Cut 3	Cut 4	Mean
H1	29,02a	32,09a	40,62a	28,06a	32,44ª
H2	29,74a	33,26a	38,35a	28,81a	32,53ª
H3	27,40b	33,18a	38,34a	27,47a	31,59ª
H4	27,27b	33,94a	31,56a	28,43a	30,30ª
H5	28,69a	33,89a	33,80a	28,53a	31,22ª
H6	27,60b	33,72a	34,77a	28,47a	31,13ª
H7	25,89b	34,70a	38,13a	27,51a	31,55ª
H8	26,85b	34,09a	40,65a	26,48a	32,01ª
H9	29,07a	32,88a	38,43a	30,81a	32,79ª
H10	28,53a	33,47a	35,15a	28,90a	31,51ª
H11	30,07a	32,71a	39,06a	31,56a	33,35ª
H12	27,15b	31,60a	34,14a	28,83a	30,42ª
H13	28,64a	32,65a	35,36a	28,80a	31,36ª
H14	27,44b	30,99a	38,60a	28,20a	31,30ª
H15	27,92b	32,28a	38,38a	27,26a	31,46ª
Mean	28,09	33,03	37,02	28,54	31,66

* Means followed by the same letter do not differ statistically from each other, in the column, by the Scott-Knott test at 5% of probability.

For the number of tillers (NT) trait evaluated in 15 hybrids obtained from circular diallel crosses in four cuts, by means of the Scott-Knott test for comparison of means at 5% probability, depicted in Table 5, there was a significant difference at 5% probability level for all evaluation cuts, with the exception of cut 2, in which the genotypes did not display significant differences. In the total yield analysis of the four cuts, there were also no significant differences ($P<0.05$).

Table 5. Mean values for the number of tillers (NP) trait of the four evaluation cuts in 15 hybrids resulting from circular diallel crosses following the Scott-Knott test at 5% probability. Campos dos Goytacazes, RJ, 2014-2017.

Genotype	Number of Tillers				
	Cut 1	Cut 2	Cut 3	Cut 4	Mean
H1	18,40b	21,86a	9,53b	10,76b	15,14ª
H2	19,40b	17,80a	10,33b	9,73b	14,31ª
H3	22,13b	17,86a	10,66b	9,71b	15,09ª
H4	18,26b	19,13a	9,73b	9,26b	14,10ª
H5	20,60b	21,26a	9,20b	11,86b	15,73ª
H6	17,06b	18,13a	7,48b	10,60b	13,32ª
H7	26,00a	26,40a	16,93a	17,53a	21,71ª
H8	20,55b	23,40a	10,65b	10,40b	16,25ª
H9	19,60b	20,53a	9,13b	12,18b	15,36ª
H10	21,80b	17,00a	9,77b	11,68b	15,06ª
H11	28,53a	27,46a	15,33a	20,80a	23,03ª
H12	18,73b	22,06a	10,56b	12,40b	15,94ª
H13	18,40b	21,86a	9,53b	10,76b	19,98ª
H14	19,40b	17,80a	10,33b	9,73b	22,80ª
H15	22,13b	17,86a	10,66b	9,71b	20,85ª
Mean	21,91	21,99	11,58	13,5	17,25

* Means followed by the same letter do not differ statistically from each other, in the column, by the Scott-Knott test at 5% of probability.

The H7 (IAC-Campinas x IJ 7139), H11 (Capim Cana D'Africa x Guaçu/I.Z.2), and H14 (Cameroon x Cuba-115) hybrids were superior in all the evaluation cuts that presented significant differences (1^{st}, 3^{rd}, and 4^{th}). The H13 (Cameroon x Guaçu/I.Z.2) and H15 (CPAC x Cuba-115) hybrids were superior in only 2 cuts, that is, the H13, in cuts 1 and 4; and the H15, in cuts 3 and 4, with the highest number of tillers found being 23 in the H11 hybrid (Capim Cana D'Africa x Guaçu/I.Z.2), in the 1^{st} evaluation cut (Table 8).

With respect to the plant height (HEI) trait, significant differences (P<0.05) were found only in the 3^{rd} evaluation cut (Table 6), with the formation of two groups, in which the H7 (IAC-Campinas x IJ 7139), H11 (Capim Cana D'África x Guaçu/I.Z.2, H13 (Cameroon x Guaçu/I.Z.2), H14 (Cameroon x Cuba-115), and H15 (CPAC x Cuba-115) hybrids displayed the best performance when comparing to the other hybrids evaluated.

Table 6. Mean values for the Height (HEI) trait of the four evaluation cuts in 15 hybrids resulting from circular diallel crosses following the Scott-Knott test at 5% probability. Campos dos Goytacazes, RJ, 2014-2017.

Genotype	Plant Height (m)				
	Cut 1	Cut 2	Cut 3	Cut 4	Mean
H1	3,43a	2,72a	1,73b	2,26a	2,54ª
H2	3,68a	2,62a	1,98b	2,15a	2,60ª
H3	3,44a	2,58a	1,79b	2,61a	2,49ª
H4	3,50a	2,61a	1,92b	2,14a	2,56ª
H5	3,60a	2,72a	2,01b	2,50a	2,64ª
H6	3,54a	2,66a	1,69b	2,32a	2,48ª
H7	3,62a	2,69a	2,36a	2,47a	2,78ª
H8	3,42a	2,84a	1,86b	2,14a	2,55ª
H9	3,54a	2,68a	1,61b	2,13a	2,54ª
H10	3,49a	2,58a	1,80b	2,23a	2,51ª
H11	3,62a	2,97a	2,51a	2,22a	2,93ª
H12	3,18a	2,68a	1,80b	2,03a	2,45ª
H13	3,73a	2,85a	2,38a	2,44a	2,86ª
H14	3,51a	2,71a	2,11a	2,06a	2,66ª
H15	3,59a	2,72a	2,34a	2,33a	2,78ª
Mean	3,53	2,71	1,99	2,27	2,62

* Means followed by the same letter do not differ statistically from each other, in the column, by the Scott-Knott test at 5% of probability.

The values ranged from 3,68 m, for the H2 hybrid (Cubano Pinda x CPAC), in the 1st evaluation cut, to 1,61 m, for the H9 hybrid (IAC-Campinas x Guaçu/I.Z.2), in the 3rd evaluation cut. The mean values of the 15 hybrids evaluated ranged from 3.53 m, in the 1st cut, to 1,99 m in the 3rd section. Results found are superior to those of Menezes et al. (2014), who obtained the highest hybrid, with a mean height of 2,60 m. Lima et al. [25], reported similar values with the same cut interval, achieving a mean of 3,05 m, in Nova Odessa (SP), and 3,37 m, in Brotas (SP).

The stem diameter is a very relevant trait for the elephant grass culture, considering that it has a positive correlation with dry matter yield [26]. Table 7 depicts the mean estimates of the stem diameter (SD) trait evaluated in 15 hybrids resulting from circular diallel crosses in four cuts using the Scott-Knott test for comparison of means at 5% probability.

As shown, no significant differences were found between genotypes in any of the cuts under analysis, with the highest values found being 15,78, 16,89, 14,87, and 19,26 mm in the 1st, 2nd, 3rd, and 4th cuts, respectively. Results confirm those of Oliveira et al. [16], who observed mean values of 13,7 and 13,3 mm for the 1st and 2nd cuts of 85 elephant grass genotypes evaluated for energy use. Pereira et al. [27], also identified similar values of stem diameter, obtaining a mean of 10,8 mm.

Table 7. Mean values for stem diameter (SD) trait of the four evaluation cuts in 15 hybrids resulting from circular diallel crosses following the Scott-Knott test at 5% probability. Campos dos Goytacazes, RJ, 2014-2017.

Genotype	Stem Diameter (mm)				
	Cut 1	Cut 2	Cut 3	Cut 4	Mean
1	15,05a	14,71a	9,40a	16,92a	14,02a
2	15,77a	15,56a	11,27a	16,84a	14,86a
3	14,78a	15,57a	11,10a	17,85a	14,83a
4	15,24a	14,90a	11,53a	18,53a	15,05a
5	15,69a	15,26a	12,40a	17,87a	15,3a
6	15,45a	15,28a	11,77a	15,59a	14,52a
7	16,32a	15,57a	13,07a	19,16a	16,03a
8	15,30a	16,54a	12,54a	17,46a	15,46a
9	14,90a	15,41a	11,73a	17,11a	14,79a
10	14,34a	14,42a	10,98a	18,17a	14,48a
11	15,67a	16,89a	14,13a	19,26a	16,49a
12	13,58a	15,60a	11,57a	15,20a	16,49a
13	15,35a	16,66a	14,87a	17,60a	16,49a
14	15,65a	14,90a	11,60a	17,84a	16,12a
15	15,38a	16,41a	13,53a	16,99a	15,58a
Mean	15,23	15,56	12,10	17,49	15,37

* Means followed by the same letter do not differ statistically from each other, in the column, by the Scott-Knott test at 5% of probability.

4. CONCLUSION

Most of the traits evaluated for both sections, with the exception of %DM and SD, reported significant values for the genotypes, indicating genetic variability;

The G6 (CPAC), G7 (IJ 7139), and G9 (Guaçu/I.Z.2) genitors showed the highest values of general combining ability (ĝi,), pointing out they will contribute to increasing the quality of the main traits of the crop in breeding programs for energy purposes;

The H11 hybrid (Capim Cana D'África x Guaçu/I.Z.2) showed positive values for the ŝii effect in all five traits evaluated, being considered, then, a potential individual for use aiming at the biomass energy production.

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