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Pre-breeding of elephant grass for energy purposes and biomass analysis in Campos dos Goytacazes- RJ, Brazil

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The objective of this study was to evaluate the morpho-agronomic traits of eighty five accessions of elephant grass (*Pennisetum purpureum* Schum.) from the germplasm bank located at the Experimental Field of the State Center for Research on Bioenergy and Waste Recovery (*Centro Estadual de Pesquisa em Agroenergia e Aproveitamento de Resíduos*). The experimental design was a randomized block with two replicates, in an annual-harvest system. The evaluated traits were: percentage of dry matter (%DM), dry matter yield (DMY), number of tillers per linear meter (NT), plant height (HGT), stem diameter (SD), leaf blade width (LW) and leaf blade length (LL). Each cut and variable underwent variance analysis and the Scott-Knott test (P<0.05). Tocher's optimization method, Mahalanobis distance and canonic variables were used for the multi-traits, and importance of the characters in the canonic variables. The following elite genotypes were identified by the Scott-Knott test at 5%: Rico 534-B, Taiwan A-144, Napier S.E.A., Mole de Volta Grande, Teresópolis, Taiwan A-46, Duro de Volta Grande, Turrialba, Taiwan A-146, Cameroon Piracicaba, Taiwan A-121, P241 Piracicaba, Elefante Cachoeira Itapemirim, Guaco/I.Z.2, Cameroon, IJ 7126 cv EMPASC 310, IJ 7139, Australiano, 10 AD IRI, and Pasto Panamá. By the analysis of the canonic variables, the first two accumulated 64.6457% of variance. Regarding the relative importance of the evaluated traits, the leaf blade length at cut two was the most important. By Tocher's optimization method, the eighty five accessions were divided into twenty five groups, indicating a high variability in the germplasm bank.

Key words: *Pennisetum purpureum*, Tocher's optimization, Mahalanobis distance, elephant grass.

INTRODUCTION

The search for alternatives to reduce the use of fossil fuels for energy production has increased worldwide in the past years due to the elevated international price of oil and its derivatives, and especially due to the concerns with the environmental and climatic changes (Morais et al., 2009). A prominent alternative today is the use of

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plant biomass as a source of energy insofar as its combustion only recycles the CO_2 that has been removed from the atmosphere by photosynthesis (Quesada et al., 2003).

Pennisetum purpureum Schum., popularly known as elephant grass, is a native perennial *Poaceae* from tropical Africa, common to the fertile valleys between the latitudes 10° N and 10° S, having an annual precipitation of over 1,000 m. It was discovered by Colonel Napier in 1905 and later spread throughout Africa. In 1920 it was introduced in Brazil, from Cuba (Carvalho et al., 1995; Deresz, 1999; Rodrigues et al., 2001; Pereira et al., 2008; Lima et al., 2010). This forage plant was well-disseminated all over the country in view of its good adaptation to the tropical environment, growing well from the sea level to altitudes of 2,200 m, between temperatures of 18 and 30°C and precipitation of 800 to 4,000 mm (Pereira et al., 2008; Lima et al., 2010).

The elephant grass is among the species with high photosynthetic efficiency, which results in a great capacity to accumulate dry matter (Queiroz Filho et al., 2000; Quesada et al., 2003; Boddey et al., 2004). Thus, in the recent years researchers have demonstrated a great interest in producing energy from plant biomass (Quesada et al., 2004).

This objective would require further studies on the identification of elephant-grass genotypes, especially so as to reveal accessions with ideal traits for biomass production aiming at energy purposes (Cavalcante and Lira, 2010; Zanetti, 2010), which can be utilized in breeding programs.

Therefore, it is extremely important to insert and maintain this species in a germplasm bank to store and provide accessions, preserve the genetic variability for the future, provide information on the accessions and identify traits of interest for breeding programs (Nass and Paterniani, 2000). However, it is known that there is a low use of the plant genetic resources in germplasm banks due to the lack of documentation, description and proper evaluation of the collections (Nass and Paterniani, 2000). The genetic divergence can be based on morphological traits which will guide the targeted crosses aiming to maximize the hybrid vigor (Schneider, 2013). Based on the foregoing, the objective of this study is to estimate the genetic diversity among 85 accessions of elephant grass through morphological traits and considering the annual productivity of the accessions so as to identify the elite genotypes, providing bases for the pre-breeding activities to guide planned crosses.

MATERIALS AND METHODS

Installation and development of the experiment

The experiment was conducted at State Center for Research on Bioenergy and Waste Recovery (*Centro Estadual de Pesquisas em Agroenergia e Aproveitamento de Resíduos*), located in the city of Campos dos Goytacazes (coordinates: 21° 19' 23'' S latitude and 41° 19' 40'' W longitude; elevation of 20 to 30 m). The climate in this region, according to the Köppen (1948) classification, is an Aw (hot and humid tropical); dry in the winter, rainy in the summer, and with an annual precipitation of approximately 1.152 mm. The soil is classified as a Yellow Oxisol, which has the following characteristics: pH, 5.5; phosphorus, 18 mg dm^{-3}; potassium, 83 mg dm^{-3}; Ca, 4.6 cmolc dm^{-3}; Mg, 3.0 cmolc dm^{-3}; Al, 0. 1 cmolc dm^{-3}; H + Al, 4.5 cmolc dm^{-3}; and C 1.6%.

The genetic material consists of 85 genotypes of elephant grass (Table 1) from the Active Germplasm Bank of Elephant Grass (BAG - CE) of Embrapa Dairy Cattle, located in Coronel Pacheco/MG. The germplasm bank was planted in February, by distributing whole stems into the furrows, two per furrow, positioned with their base in contact with the apex of the next plant. After this distribution in the furrows, they were cut into pieces containing two or three buds. An experimental design of randomized blocks with two replicates was adopted, and the plot was formed by a 5.5-m row with 2-m spacing, totaling 11 m^2. The floor area utilized was a sample collected from the center of the plot.

In fertilization at planting, each row received 60 g of single superphosphate, and 50 days after planting topdressing was performed with 70 g of urea and 40 g potassium chloride (KCl) per row and 24 kg K_2O (potassium oxide) per hectare. After the establishment phase, on December 15, 2011, plot-leveling and replanting were performed to reduce flaws in the rows. The first cut was performed after one year of growth, on 11/27/2012; the second cut was made on 11/05/2013, after another year of growth.

Evaluated traits

Morpho-agronomic traits were evaluated in all genotypes after each year of continuous growth, with whole-plant samples.

Morpho-agronomic traits

(a) Dry matter yield (DMY): The biomass of each plot was weighed, and then sub-samples were collected, chopped, and conditioned in paper bags to be dried in a forced-air oven at 65°C. After 72 h the samples were once again weighed to obtain the result of air-dried samples (ADS).
(b) Percentage of dry matter (%DM): Two grams of the ADS were ground in a Wiley mill (1 mm sieve) and then dried in an oven for 16 h at 105°C to obtain the oven-dried sample (ODS). The percentage of DM was estimated from the result of the air- (ADS) and oven-dried (ODS) samples.
(c) Number of tillers (NT): The number of tillers was counted in 1.5 linear meters of one of the rows of the plot, and subsequently converted to number of tillers per linear meter.
(d) Plant height, in m (HGT): The height was measured with a tape measure, taking the average of three measurements in each plot.
(e) Average diameter of the stem at the base of the plant, in cm (SD): The measurements were made approximately 10 cm above the soil, obtaining the average of three measurements using a digital caliper.
(f) Leaf blade width and length, in cm (LW and LL, respectively): Measured using a centimeter ruler, taking the average of three measurements.

Statistical analyses

The obtained data, for each trait, were subjected to variance analysis using the GENES (Cruz et al., 2013) computer software, according to the following statistical model:

$$Yij = M + Gi + Bj + eij,$$

Table 1. Genotypes of elephant grass from the Active Germplasm Bank of Elephant grass (BAG-CE), Campos dos Goytacazes, RJ, 2012/2013.

S/No	Genotype	Origin	S/No	Genotype	Origin
1	Elefante da Colômbia	Colombia	44	Capim Cana D'África	Brazil
2	Mercker	Brazil	45	Gramafante	Brazil
3	Três Rios	Brazil	46	Roxo	Brazil
4	Napier Volta Grande	Brazil	47	Guaco/I.Z.2	Brazil
5	Mercker Santa Rita	Brazil	48	Cuba-115	Cuba
6	Pusa Napier N 2	Índia	49	Cuba-116	Cuba
7	Gigante de Pinda	Brazil	50	Cuba-169	Cuba
8	Napier N 2	Brazil	51	King Grass	Cuba
9	Mercker S.E.A	Brazil	52	Roxo Botucatu	Brazil
10	Taiwan A-148	Brazil	53	Mineirão IPEACO	Brazil
11	Porto Rico 534-B	Brazil	54	Vruckwona Africano	Brazil
12	Taiwan A-25	Brazil	55	Cameroon	Brazil
13	Albano	Colombia	56	CPAC	Brazil
14	Hib, Gigante Colômbia	Colombia	57	Guacu	Brazil
15	Pusa Gigante Napier	Índia	58	Napierzinho	Brazil
16	Elefante Híbrido 534-A	Brazil	59	IJ 7125 cv EMPASC 308	Brazil
17	Costa Rica	Costa Rica	60	IJ 7126 cv EMPASC 310	Brazil
18	Cubano Pinda	Brazil	61	IJ 7127 cv EMPASC 309	Brazil
19	Mercker Pinda	Brazil	62	IJ 7136 cv EMPASC 307	Brazil
20	Mercker Pinda México	Brazil	63	IJ 7139	Brazil
21	Mercker 86 México	Colombia	64	IJ 7141 cv EMPASC 306	Brazil
22	Taiwan A-144	Brazil	65	Goiano	Brazil
23	Napier S.E.A,	Brazil	66	CAC-262	Brazil
24	Taiwan A-143	Brazil	67	Ibitinema	Brazil
25	Pusa Napier N 1	Índia	68	903-77 ou Australiano	Brazil
26	Elefante de Pinda	Colombia	69	13 AD	Brazil
27	Mineiro	Brazil	70	10 AD IRI	Brazil
28	Mole de Volta Grande	Brazil	71	07 AD IRI	Brazil
29	Porto Rico	Brazil	72	Pasto Panamá	Brazil
30	Napier	Brazil	73	BAG - 92	Brazil
31	Mercker Comum	Brazil	74	09 AD IRI	Brazil
32	Teresopólis	Brazil	75	11 AD IRI	Brazil
33	Taiwan A-46	Brazil	76	05 AD IRI	Brazil
34	Duro de Volta Grande	Brazil	77	06 AD IRI	Brazil
35	Mercker Comum Pinda	Brazil	78	01 AD iIRI	Brazil
36	Turrialba	Brazil	79	04 AD IRI	Brazil
37	Taiwan A-146	Brazil	80	13 AD IRI	Brazil
38	Cameroon - Piracicaba	Brazil	81	03 AD IRI	Brazil
39	Taiwan A-121	Brazil	82	02 AD IRI	Brazil
40	Vrukwona	Brazil	83	08 AD IRI	Brazil
41	P241 Piracicaba	Brazil	84	União	Brazil
42	IAC-Campinas	Brazil	85	Pesagro Bord	Brazil
43	Elefante Cachoeira Itapemirim	Brazil			

where:

Y_{ij}: observation of the i-th genotype in the j-th block;
m: overall constant associated with this random variable;
G_i: effect of the i-th genotype;
B_j: effect of the j-th block;
e_{ij}: experimental error associated with observation Y.

Subsequently, the mean values of the genotypes were clustered for each variable within each evaluation, utilizing the Scott and Knott

Table 2. Summary of the variance analysis in randomized blocks for percentage of dry matter (%DM) and dry matter yield (DMY) at cuts 1 and 2, and total dry matter yield in t. ha^{-1} evaluated in 85 genotypes of elephant grass.

Source of variability	DF	Mean squared				
		Cut 1		Cut 2		Total
		%DM	DMY	%DM	DMY	DMY
Blocks	1	15.72	60.57	1.24	152.91	20.99
Treatments	84	63.03*	336.90**	21.38*	388.20*	1141.69**
Residue	84	43.27	167.36	14.38	259.48	593.98
Mean		35.67	35.01	36.73	41.32	76.33
CV (%)		18.43	36.95	10.33	38.98	31.93

** and * - significant at 1 and 5% probability, respectively, by the F test.

(1974) clustering method. And for multivariate analyses, we used: the canonic variables, eigenvalues and eigenvectors, Mahalanobis distance (D_2) and Tocher's clustering method. All analyzes were obtained with the aid of the GENES computer software (Cruz, 2013).

Clustering was performed via Tocher's optimization method via Mahalanobis distance (D_2), which adopts the criterion that the average of dissimilarity measures, within each group, should be smaller than the distances between any groups. By the dissimilarity matrix, we identify the pair of most similar accessions; these accessions will form the initial group, in which the possibility of including new accessions will be evaluated (Cruz and Regazzi, 2001).

RESULTS AND DISCUSSION

Variance analysis and mean clustering by the Scott-Knott test for percentage of dry matter and dry matter yield

The results demonstrate that there were significant differences by the F test at 1% probability for dry matter yield (DMY), in t.ha^{-1} at cut 1 (year 2012) and in the total; however, at cut 2 it was significant at 5% probability (year 2013). Still, the percentage of dry matter (%DM) from both cuts showed significance at 5% probability by the F test (Table 2).In a study conducted by Italiano et al. (2006) with ten genotypes of *P. purpureum*, it was found that at 60 days of age DMY was also significant at 1% probability.

The significant differences observed between the means of accessions of *P. purpureum*, regarding %DM and DMY, indicate that there is genetic variability in the active collection of germplasm bank, making it possible to select the best genotypes (Araujo et al., 2008). The experimental coefficients of variation (CV) for the DMY of cut 1, cut 2 and the total were similar; however, the lowest CV for DMY was found in the total (31.93%), whereas the highest value was observed in cut 2 (38.98%). On the other hand, the CV for %DM was lower than that of DMY, with 18.43% in cut 1 and 10.33% in cut 2 (Table 2).

The coefficients of variation indicate the precision of the experiment, and in agricultural field trials they can be considered low when below 10%, medium from 10 to 20%, high from 20 to 30%, and very high when above 30% (Fonseca and Martins, 1996); thus, the coefficient of variation for the two %DM values were medium, whereas the three values for DMY were considered very high, according to this classification. However, it should be emphasized that although the CV was very high for the DMY variable, it can be justified by the fact that three distinct variables are related to estimate this character: fresh-matter weight of the plot, ADS (sample dried at 65°C) and ODS (sample dried at 105°C). Other studies conducted with elephant grass have presented CV considered high or very high for DMY (Daher et al., 2004; Oliveira et al., 2012; Oliveira, 2013). However, %DM has shown a lower CV, ranging from low to medium (Oliveira et al., 2012; Oliveira, 2013), just as in the present study.

According to the data from the variance analysis (Table 2), the average dry matter yield in 2012 (35.01 t.ha^{-1}) was similar to that of 2013 (41.32 t.ha^{-1}). This was likely because there was no large variation between the precipitations of 2012 (781.1 mm) and 2013 (907.8 mm) (Table 3). Several studies have already demonstrated that the amount of available water interferes with the productivity of the plant, whose development improves as the availability of water is increased (Daher et al., 2000; Ribeiro et al., 2009; Vitor et al., 2009).

Although in the variance analysis the %DM showed a significant difference ($P<0.05$) at both cuts (Table 2), there were no significant differences among the genotypes by the Scott-Knott test at 5% for both cuts 1 and 2, and thus no groups were formed (Table 4). Despite the lack of significant difference, in cut 1 the %DM varied from 50.94 to 20.48% in the genotypes Napierzinho and Napier Volta Grande, respectively.

However, in cut 2 the highest %DM, 44.99% was found in genotype Australiano, and the lowest, 29.02%, in King Grass. Corroborating this result, in an evaluation with elephant grass at 51 days of growth, it was found that the %DM had a significant difference in the variance

Table 3. Monthly precipitation (mm) during the experiment.

2012		2013	
Month	**Precipitation (mm)**	**Month**	**Precipitation (mm)**
January	216.5	January	125.7
February	11.7	February	44.3
March	73.6	March	230.2
April	14.2	April	103.2
May	147.2	May	41.6
June	74.0	June	8.7
July	5.9	July	67.1
August	59.8	August	57.0
September	21.6	September	45.2
October	12.5	October	26.4
November	133.7	November	158.4
December	10.4	December	-
Total	781.1	Total	907.8

Source: Evapotranspiration Monitoring Station of the Centro Estadual de Pesquisa em Agroenergia e Aproveitamento de resíduos, Pesagro - Rio,Campos dos Goytacazes-RJ.

analysis (P<0.05%), but this difference was not detected in the Scott-Knott test at 5% (Oliveira et al., 2012) A similar result was presented with 73 genotypes of *P. purpureum* at six months of age (Oliveira, 2013). Though in some studies no groups were formed by the Scott-Knott test at 5% (Oliveira et al., 2012; Oliveira, 2013), the analysis of the dry matter of each genotype (%DM) is very important, given that 90% of the plant cells may consist of water (Oliveira, 2013). For the variable DMY, at cut 1, the average production varied between 69.58 and 13.96 $t.ha^{-1}$, for genotypes Taiwan A-121 and Napier Volta Grande, respectively. The Scott-Knott clustering at 5% probability generated two groups, in which in 30 genotypes can be found in group "a", and the other 55 in group "b". In cut 2, the average DMY was between 78.01 $t.ha^{-1}$, for genotype Australiano, and 11.48 $t.ha^{-1}$, in genotype 07 AD IRI. Two groups were formed, with thirty three of them being in group "a", of 85 genotypes analyzed (Table 4). For total dry matter yield, just as in cut 2, the highest value was obtained by genotype Australiano, reaching 133.78 $t.ha^{-1}$, and genotype BAG-92 revealed the lowest mean, 32.11 $t.ha^{-1}$. In the Total, the groups formed were also two; however, group "a" had 39 genotypes in it. Thus, the genotypes considered elite were those that composed group "a" in cut 1, cut 2 and in the total, Porto Rico 534-B, Taiwan A-144, Napier S.E.A., Mole de Volta Grande, Teresópolis, Taiwan A-46, Duro de Volta Grande, Turrialba, Taiwan A-146, Cameroon-Piracicaba, Taiwan A-121, P241 Piracicaba, Elefante Cachoeira Itapemirim, Guaco/I.Z.2, Cameroon, IJ 7126 cv EMPASC 310, IJ 7139, Australiano, 10 AD IRI and Pasto Panamá. Based on that, these genotypes can be indicated in the future for possible crosses aiming to increase the genetic gain for this trait.

A similar study has been conducted (Oliveira, 2013) with seventy three of the elephant-grass genotypes described herein, and for the DMY variable the genotypes considered elite, and that corroborated this study were Taiwan A-46, Duro de Volta Grande, Guaco/I.Z.2 and Pasto Panamá; however, ten genotypes that were described as having good productivity were not considered elite genotypes in the current study. Just as in this study, genotype Cameroon has stood out for its productivity, and when compared with two other genotypes of elephant grass it was chosen as having the highest dry matter yield, for energy purposes (Quesada et al., 2004). This same result agrees with an analysis conducted with five other elephant-grass genotypes, which also concluded that Cameroon has one of the greatest dry-biomass yields, on a nine-month harvest system (Morais et al., 2009). Unlike these results, at ten months of growth, genotype Mercker 86-Mexico has gained prominence for producing 56.56 $t.ha^{-1}$ (Rossi, 2010).

To select the elite genotypes of elephant grass one must bear in mind that because it is a perennial culture, usually implanted to be utilized for some years, elephant-grass genotypes should be productive throughout the entire culture, and so it is more interesting to the produce that the genotypes have stable performance over the harvests (Souza Sobrinho et al., 2005).

Variance analysis of the morpho-agronomic traits

All morpho-agronomic traits evaluated showed significant differences by the F test (P<0.01), indicating that there is genetic variability in the active germplasm bank and also proving that the descriptors utilized among the genotypes demonstrated different degrees of discrimination. The

Table 4. Percentage of dry matter (%DM) and dry matter yield (DMY) at cuts 1 and 2, and total dry matter yield (cut 1 + cut 2) of the 85 genotypes of elephant grass.

Genotype	Cut 1		Cut 2		Total
	%DM (%)	DMY ($t.ha^{-1}$)	%DM (%)	DMY ($t.ha^{-1}$)	DMY ($t.ha^{-1}$)
Elefante da Colômbia	40.92 [a1]	28.67 [b]	36.66 [a]	27.48 [b]	56.15 [b]
Mercker	27.70 [a]	32.57 [b]	34.14 [a]	55.93 [a]	88.504 [a]
Três Rios	31.60 [a]	35.97 [b]	32.49 [a]	49.68 [a]	85.66 [a]
Napier Volta Grande	20.48 [a]	13.96 [b]	31.88 [a]	27.36 [b]	41.39 [b]
Mercker Santa Rita	33.00 [a]	30.09 [b]	39.04 [a]	32.41 [b]	62.51 [b]
Pusa Napier N 2	42.97 [a]	18.25 [b]	40.31 [a]	36.88 [b]	55.13 [b]
Gigante de Pinda	38.35 [a]	33.43 [b]	39.22 [a]	56.01 [a]	89.44 [a]
Napier N 2	44.20 [a]	17.23 [b]	40.38 [a]	22.17 [b]	39.40 [b]
Mercker S.E.A	49.95 [a]	26.87 [b]	39.93 [a]	31.70 [b]	58.56 [b]
Taiwan A-148	32.40 [a]	27.05 [b]	39.72 [a]	37.31 [b]	64.37 [b]
Porto Rico 534-B	38.99 [a]	41.02 [a]	36.96 [a]	60.50 [a]	101.52 [a]
Taiwan A-25	28.82 [a]	16.52 [b]	37.53 [a]	33.80 [b]	50.32 [b]
Albano	31.78 [a]	19.65 [b]	39.41 [a]	33.28 [b]	52.93 [b]
Hib, Gigante Colômbia	36.81 [a]	24.56 [b]	35.53 [a]	35.87 [b]	60.42 [b]
Elefante Híbrido 534-A	26.86 [a]	19.13 [b]	32.57 [a]	40.72 [b]	59.84 [b]
Costa Rica	32.66 [a]	28.02 [b]	33.85 [a]	36.48 [b]	64.50 [b]
Cubano Pinda	33.80 [a]	27.51 [b]	35.80 [a]	41.38 [b]	68.88 [b]
Mercker Pinda	42.86 [a]	27.28 [b]	37.47 [a]	41.57 [b]	68.85 [b]
Mercker Pinda México	34.56 [a]	20.78 [b]	39.28 [a]	40.15 [b]	60.93 [b]
Mercker 86 México	32.82 [a]	24.03 [b]	33.69 [a]	42.75 [b]	66.78 [b]
Taiwan A-144	39.28 [a]	47.54 [a]	37.16 [a]	58.75 [a]	106.29 [a]
Napier S.E.A.	41.32 [a]	48.87 [a]	40.46 [a]	54.87 [a]	103.74 [a]
Taiwan A-143	27.78 [a]	23.77 [b]	31.95 [a]	25.39 [b]	49.17 [b]
Pusa Napier N 1	31.85 [a]	29.04 [b]	32.34 [a]	58.38 [a]	87.42 [a]
Elefante de Pinda	31.06 [a]	24.86 [b]	35.76 [a]	35.35 [b]	60.21 [b]
Mineiro	31.99 [a]	41.14 [a]	31.29 [a]	34.74 [b]	75.88 [b]
Mole de Volta Grande	37.25 [a]	56.96 [a]	38.63 [a]	47.28 [a]	104.24 [a]
Porto Rico	36.11 [a]	36.93 [b]	42.20 [a]	59.68 [a]	96.61 [a]
Napier	33.98 [a]	36.32 [b]	41.40 [a]	60.83 [a]	97.16 [a]
Mercker Comum	37.69 [a]	23.34 [b]	37.53 [a]	31.44 [b]	54.78 [b]
Teresopólis	39.33 [a]	44.41 [a]	36.58 [a]	50.03 [a]	94.44 [a]
Taiwan A-46	34.93 [a]	63.96 [a]	38.12 [a]	58.56 [a]	122.51 [a]
Duro de Volta Grande	40.20 [a]	50.93 [a]	36.07 [a]	47.11 [a]	98.04 [a]
Mercker Comum Pinda	42.72 [a]	46.90 [a]	39.82 [a]	38.33 [b]	85.23 [a]
Turrialba	31.49 [a]	40.91 [a]	33.73 [a]	57.96 [a]	98.87 [a]
Taiwan A-146	31.37 [a]	39.13 [a]	31.22 [a]	49.33 [a]	88.46 [a]
Cameroon - Piracicaba	36.31 [a]	65.05 [a]	35.78 [a]	59.56 [a]	124.61 [a]
Taiwan A-121	41.17 [a]	69.58 [a]	38.96 [a]	57.53 [a]	127.11 [a]
Vrukwona	32.09 [a]	39.32 [a]	34.60 [a]	35.14 [b]	74.45 [b]
P241 Piracicaba	41.62 [a]	64.81 [a]	36.73 [a]	63.72 [a]	128.53 [a]
IAC-Campinas	32.65 [a]	43.73 [a]	36.39 [a]	38.00 [b]	81.73 [a]
Elefante Cachoeira Itapemirim	36.86 [a]	64.14 [a]	38.69 [a]	69.32 [a]	133.47 [a]
Capim Cana D'África	37.52 [a]	41.82 [a]	36.40 [a]	25.64 [b]	67.47 [b]
Gramafante	32.15 [a]	35.41 [b]	42.26 [a]	56.23 [a]	91.64 [a]
Roxo	34.24 [a]	31.26 [b]	34.14 [a]	26.00 [b]	57.26 [b]
Guaco/I.Z.2	31.51 [a]	48.19 [a]	38.30 [a]	62.04 [a]	110.24 [a]
Cuba-115	35.02 [a]	31.01 [b]	32.91 [a]	21.42 [b]	52.43 [b]
Cuba-116	35.39 [a]	53.45 [a]	37.07 [a]	41.66 [b]	95.11 [a]

Table 4. Contd.

Cuba-169	28.00 [a]	21.98 [b]	35.38 [a]	44.42 [a]	66.41 [b]
King Grass	36.16 [a]	53.94 [a]	29.02 [a]	29.70 [b]	83.64 [a]
Roxo Botucatu	44.11 [a]	28.86 [b]	29.96 [a]	27.08 [b]	55.94 [b]
Mineirão IPEACO	31.78 [a]	34.08 [b]	37.53 [a]	51.77 [a]	85.85 [a]
Vruckwona Africano	39.25 [a]	36.83 [b]	35.19 [a]	43.71 [b]	84.03 [a]
Cameroon	36.23 [a]	47.70 [a]	36.58 [a]	47.20 [a]	87.74 [a]
CPAC	37.61 [a]	36.65 [b]	33.55 [a]	40.04 [b]	64.11 [b]
Guacu	26.45 [a]	24.63 [b]	37.70 [a]	27.46 [b]	64.49 [b]
Napierzinho	50.945 [a]	32.4015 [b]	34.155 [a]	39.852 [b]	47.8945 [b]
IJ 7125 cv EMPASC 308	37.56 [a]	39.05 [a]	37.82 [a]	15.49 [b]	106.71 [a]
IJ 7126 cv EMPASC 310	38.95 [a]	50.92 [a]	37.77 [a]	67.66 [a]	88.56 [a]
IJ 7127 cv EMPASC 309	30.88 [a]	49.66 [a]	35.45 [a]	37.63 [b]	98.09 [a]
IJ 7136 cv EMPASC 307	31.83 [a]	20.06 [b]	35.43 [a]	48.43 [a]	71.87 [b]
IJ 7139	36.75 [a]	46.23 [a]	36.62 [a]	51.81 [a]	89.94 [a]
IJ 7141 cv EMPASC 306	28.26 [a]	22.27 [b]	35.59 [a]	30.55 [b]	52.82 [b]
Goiano	31.02 [a]	26.14 [b]	29.90 [a]	34.58 [b]	60.72 [b]
CAC-262	34.87 [a]	45.60 [a]	35.83 [a]	40.32 [b]	85.92 [a]
Ibitinema	34.11 [a]	37.71 [b]	41.87 [a]	49.36 [a]	87.06 [a]
903-77 ou Australiano	34.83 [a]	55.76 [a]	44.99 [a]	78.01 [a]	133.77 [a]
13 AD	40.54 [a]	32.03 [b]	36.75 [a]	28.75 [b]	60.78 [b]
10 AD IRI	36.99 [a]	40.35 [a]	39.59 [a]	52.07 [a]	92.42 [a]
07 AD IRI	35.99 [a]	20.97 [b]	38.31 [a]	11.48 [b]	32.45 [b]
Pasto Panamá	34.13 [a]	44.01 [a]	31.63 [a]	50.34 [a]	94.35 [a]
BAG - 92	37.87 [a]	19.09 [b]	36.62 [a]	13.01 [b]	32.10 [b]
09 AD IRI	44.83 [a]	31.40 [b]	39.51 [a]	30.66 [b]	62.06 [b]
11 AD IRI	42.15 [a]	27.04 [b]	39.26 [a]	31.34 [b]	58.39 [b]
05 AD IRI	34.78 [a]	29.06 [b]	39.99 [a]	39.72 [b]	68.78 [b]
06 AD IRI	35.48 [a]	28.95 [b]	37.13 [a]	41.93 [b]	70.88 [b]
01 AD iIRI	27.31 [a]	21.14 [b]	41.90 [a]	38.34 [b]	59.48 [b]
04 AD IRI	37.33 [a]	14.90 [b]	42.40 [a]	28.60 [b]	43.50 [b]
13 AD IRI	47.31 [a]	30.62 [b]	41.85 [a]	19.82 [b]	50.44 [b]
03 AD IRI	26.69 [a]	26.64 [b]	39.41 [a]	54.81 [a]	81.45 [a]
02 AD IRI	29.64 [a]	33.32 [b]	35.90 [a]	39.19 [b]	72.51 [b]
08 AD IRI	49.85 [a]	17.69 [b]	33.35 [a]	18.88 [b]	36.57 [b]
União	38.33 [a]	27.38 [b]	39.32 [a]	29.54 [b]	56.92 [b]
Pesagro Bord	33.13 [a]	28.96 [b]	33.97 [a]	19.20 [b]	48.16 [b]
Average	35.67	35.02	36.73	41.32	76.33
Standard Errors	0.56	1.21	0.32	1.36	2.25

[1/] Means followed by the same letter in the column do not differ by the Scott-Knott test at 5% probability.

greatest coefficient of variation was found in number of tillers (NT); it was considered very high, reaching 30.39% in 2012 and 38.48% in 2013. In contrast, plant height (HGT) had low CV values in both years: 6.85 and 7.88% in 2012 and 2013, respectively. The stem diameter (SD) had very close coefficients of variation in the two years: 10.59 (2012) and 10.52% (2013), considered medium (Table 5). For leaf blade width (LW), the CV was high in 2012 (23.92%) and medium in 2013 (18.65%). The leaf-blade-length variable (LL) had a medium CV, ranging from 15.59 (2012) to 18.53% (2013) (Table 6).

Corroborating this study, other experiments with elephant grass have demonstrated that the NT variable, when compared with HGT and SD, was also the one with the highest coefficient of variation (Daher et al., 2004b; Rossi et al., 2010; Xia et al., 2010; Oliveira, 2013), and HGT showed the lowest CV (Daher et al., 2004b; Rossi et al., 2010).

Clustering of means of morpho-agronomic traits by the Scott-Knott test

The number of tillers in cut 1 varied from 137.00 in

Table 5. Summary of the variance analysis for number of tiller per linear meter (NT), plant height (HGT), stem diameter (SD), blade width (LW) and length (LL) of 85 genotypes of elephant grass.

Source of variability	DF	Mean squared									
		NT		HGT (cm)		SD (mm)		LW(cm)		LL (cm)	
		Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2
Blocks	1	217.45	1609.25	0.13	15.63	87.96	308.77	0.67	0.00	1353.34	268.89
Treatments	84	1046.31**	1703.89**	0.39**	0.15**	8.64**	11.89**	0.82**	0.52**	167.05**	183.58**
Residue	84	3.352.70	7705.03	0.06	0.08	21.03	19.58	0.22	0.09	544.87	653.40
Mean		60.26	72.14	3.55	3.57	13.70	13.30	1.97	1.65	47.34	43.62
CV (%)		30.39	38.48	6.85	7.88	10.59	10.52	23.92	18.65	15.59	18.53

* -Significant at 1% probability by the F test; CV (%) - coefficient of variation.** - Significant at 1% probability by the F test; CV (%) - coefficient of variation.

Table 6. Number of tillers per linear meter (NT), plant height (HGT), stem diameter (SD) and leaf blade width (LW) and length (LL) in cuts 1 and 2, evaluated in 85 genotypes of elephant grass.

Genotypes	NT		HGT (m)		SD (mm)		LW (cm)		LL (cm)	
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2
Elefante da Colômbia	55.00 b1/	47.00 b	3.70 b	4.40 a	13.41 c	13.56 c	2.17 c	1.48 c	42.30 c	37.92 b
Mercker	53.00 b	80.00 b	4.35 a	3.80 a	14.20 b	15.50 b	3.01 a	1.58 c	47.40 c	45.41 b
Três Rios	70.50 a	114.00 a	4.20 a	3.75 a	14.14 b	14.01 b	2.76 b	1.65 c	49.20 c	42.50 b
Napier Volta Grande	41.50 b	55.00 b	3.22 c	3.80 a	14.16 b	12.80 c	3.11 a	1.63 c	44.47 c	43.50 b
Mercker Santa Rita	73.00 a	70.50 b	3.25 c	3.70 a	11.88 c	13.38 c	2.64 b	1.48 c	37.50 c	42.17 b
Pusa Napier N 2	49.00 b	54.00 b	3.10 c	3.50 b	12.95 c	13.12 c	2.35 b	1.40 c	37.72 c	34.67 b
Gigante de Pinda	82.50 a	104.50 a	3.15 c	3.02 c	13.02 c	11.79 c	2.54 b	1.33 c	40.54 c	37.50 b
Napier N 2	42.50 b	60.00 b	3.17 c	3.27 b	11.14 c	12.06 c	2.55 b	1.48 c	41.65 c	40.66 b
Mercker S.E.A	48.00 b	59.00 b	3.27 c	3.40 b	10.84 c	11.37 d	2.23 b	1.71 c	35.95 c	40.33 b
Taiwan A-148	71.50 a	56.40 b	3.70 b	3.90 a	15.10 b	11.62 d	1.48 c	1.43 c	37.27 c	43.35 b
Porto Rico 534-B	52.00 b	87.50 a	3.80 b	4.05 a	11.89 c	13.41 c	1.40 c	1.55 c	43.25 c	46.91 b
Taiwan A-25	53.00 b	41.50 b	3.70 b	3.75 a	14.08 b	11.25 d	1.25 c	1.31 c	46.52 c	43.66 b
Albano	27.00 b	31.50 b	4.15 a	4.10 a	17.19 a	16.65 a	1.63 c	1.52 c	46.63 c	42.03 b
Hib, Gigante Colômbia	49.50 b	43.50 b	3.65 b	3.62 a	12.59 c	15.86 b	1.36 c	1.18 c	41.22 c	37.45 b
Pusa Gigante Napier	66.00 a	89.00 a	3.84 b	4.15 a	14.43 b	14.90 b	2.05 c	1.37 c	64.11 b	34.91 b
Elefante Híbrido 534-A	31.00 b	45.00 b	3.50 c	3.50 b	15.91 a	17.85 a	1.90 c	1.67 c	57.06 b	47.00 b
Costa Rica	30.00 b	45.50 b	3.97 b	4.05 a	16.06 a	17.07 a	2.01 c	1.57 c	48.98 c	44.58 b
Cubano Pinda	41.00 b	40.50 b	4.56 a	3.90 a	15.70 a	18.74 a	2.81 a	1.68 c	61.17 b	45.83 b
Mercker Pinda	42.00 b	35.00 b	3.31 c	3.65 a	13.26 c	18.09 a	2.21 b	1.26 c	44.43 c	40.08 b
Mercker Pinda México	36.50 b	36.50 b	3.32 c	3.75 a	15.36 b	19.29 a	1.50 c	1.25 c	44.96 c	37.66 b
Mercker 86 México	43.00 b	43.00 b	3.97 b	4.22 a	14.21 b	18.83 a	1.11 c	1.11 c	31.46 c	29.28 b
Taiwan A-144	69.00 a	77.50 b	3.90 b	3.85 a	13.83 b	14.20 b	1.02 c	1.36 c	42.83 c	33.17 b
Napier S.E.A	71.00 a	74.00 b	3.79 b	3.85 a	13.65 c	13.68 c	1.52 c	1.40 c	48.77 c	33.18 b
Taiwan A-143	50.00 b	50.00 b	4.05 a	3.75 a	14.54 b	12.67 c	1.35 c	1.20 c	47.08 c	32.38 b
Pusa Napier N 1	33.00 b	57.00 b	3.65 b	3.90 a	17.89 a	16.56 a	1.77 c	1.16 c	46.42 c	33.17 b
Elefante de Pinda	87.65 a	69.50 b	3.02 c	3.40 b	11.73 c	11.10 d	1.21 c	1.35 c	48.78 c	33.91 b
Mineiro	88.50 a	58.50 b	3.25 c	3.45 b	12.03 c	12.04 c	1.91 c	1.60 c	46.31 c	36.30 b
Mole de Volta Grande	112.50 a	119.00 a	3.42 c	3.45 b	13.06 c	9.88 d	1.76 c	1.30 c	49.16 c	38.08 b
Porto Rico	97.50 a	105.00 a	3.02 c	3.45 b	10.92 c	10.90 d	2.06 c	1.37 c	40.20 c	40.42 b
Napier	86.50 a	89.50 a	3.10 c	3.50 b	12.49 c	11.72 c	1.88 c	1.46 c	46.19 c	40.08 b
Mercker Comum	59.50 b	81.50 b	2.92 c	3.20 b	11.16 c	11.24 d	2.14 c	1.15 c	27.11 c	32.93 b
Teresopólis	80.00 a	91.50 a	3.73 b	3.80 a	11.70 c	12.57 c	1.28 c	0.95 c	31.90 c	21.90 b
Taiwan A-46	91.00 a	112.00 a	3.52 c	3.75 a	14.02 b	12.48 c	1.23 c	1.18 c	44.31 c	37.67 b
Duro de Volta Grande	68.00 a	92.50 a	3.75 b	3.70 a	12.65 c	11.96 c	1.74 c	1.43 c	46.00 c	43.05 b
Mercker Comum Pinda	89.00 a	71.00 b	3.10 c	3.40 b	12.80 c	11.14 d	1.73 c	1.06 c	33.01 c	32.33 b
Turrialba	56.00 b	72.50 b	3.77 b	3.60 a	15.74 a	15.42 b	1.25 c	1.66 c	49.02 c	42.36 b

Table 6. Contd.

Taiwan A-146	57.00 ^{b}	39.00 ^{b}	4.21 ^{a}	3.65 ^{a}	15.66 ^{a}	13.68 ^{c}	2.12 ^{c}	1.55 ^{c}	49.67 ^{c}	45.50 ^{b}
Cameroon – Piracicaba	61.50 ^{b}	89.00 ^{a}	4.01 ^{a}	3.75 ^{a}	16.40 ^{a}	15.90 ^{b}	1.85 ^{c}	1.93 ^{c}	55.74 ^{b}	56.87 ^{a}
Taiwan A-121	87.50 ^{a}	82.50 ^{b}	3.50 ^{c}	3.45 ^{b}	11.11 ^{c}	12.73 ^{c}	3.18 ^{a}	1.81 ^{c}	42.57 ^{c}	46.75 ^{b}
Vrukwona	41.00 ^{b}	101.00 ^{a}	4.15 ^{a}	3.70 ^{a}	17.63 ^{a}	13.38 ^{c}	1.47 ^{c}	3.17 ^{a}	54.46 ^{b}	59.92 ^{a}
P241 Piracicaba	50.20 ^{b}	98.00 ^{a}	3.42 ^{c}	3.85 ^{a}	13.67 ^{c}	13.14 ^{c}	3.46 ^{a}	1.60 ^{c}	57.60 ^{b}	56.03 ^{a}
IAC-Campinas	46.00 ^{b}	78.00 ^{b}	4.05 ^{a}	3.50 ^{b}	16.56 ^{a}	12.70 ^{c}	2.12 ^{c}	2.63 ^{b}	50.34 ^{c}	56.08 ^{a}
Elefante Cachoeira Itapemirim	137.00 ^{a}	54.50 ^{b}	3.30 ^{c}	3.65 ^{a}	12.25 ^{c}	12.94 ^{c}	3.30 ^{a}	1.28 ^{c}	49.34 ^{c}	28.71 ^{b}
Capim Cana D'África	45.00 ^{b}	132.50 ^{a}	3.95 ^{b}	3.70 ^{a}	16.95 ^{a}	12.77 ^{c}	2.10 ^{c}	2.31 ^{b}	51.08 ^{c}	54.50 ^{a}
Gramafante	83.00 ^{a}	42.00 ^{b}	3.30 ^{c}	3.50 ^{b}	12.30 ^{c}	11.29 ^{d}	2.86 ^{a}	1.71 ^{c}	48.60 ^{c}	39.53 ^{b}
Roxo	40.50 ^{b}	103.50 ^{a}	3.98 ^{b}	3.95 ^{a}	13.56 ^{c}	14.59 ^{b}	1.88 ^{c}	2.06 ^{b}	55.53 ^{b}	50.30 a
Guaco/I.Z.2	64.00 ^{b}	78.50 ^{b}	4.05 ^{a}	3.80 ^{a}	13.99 ^{b}	14.87 ^{b}	2.30 ^{b}	2.71 ^{b}	58.92 ^{b}	74.00 a
Cuba-115	37.50 ^{b}	39.00 ^{b}	3.95 ^{b}	3.60 ^{a}	14.86 ^{b}	14.16 ^{b}	2.22 ^{b}	2.10 ^{b}	50.82 ^{c}	46.65 ^{b}
Cuba-116	80.00 ^{a}	61.50 ^{b}	4.15 ^{a}	3.85 ^{a}	16.08 ^{a}	13.79 ^{c}	2.30 ^{b}	3.57 ^{a}	47.29 ^{c}	73.55 a
Cuba-169	31.65 ^{b}	47.50 ^{b}	3.30 ^{c}	3.20 ^{b}	16.14 ^{a}	15.21 ^{b}	3.30 ^{a}	2.40 ^{b}	68.26 ^{a}	60.50 a
King Grass	64.50 ^{b}	72.50 ^{b}	3.73 ^{b}	4.15 ^{a}	14.59 ^{b}	13.27 ^{c}	1.67 ^{c}	1.78 ^{c}	53.81 ^{b}	55.58 a
Roxo Botucatu	32.00 ^{b}	37.50 ^{b}	3.80 ^{b}	4.22 ^{a}	14.83 ^{b}	17.57 ^{a}	1.79 ^{c}	1.96 ^{c}	49.13 ^{c}	50.78 a
Mineirão IPEACO	75.00 ^{a}	101.00 ^{a}	3.45 ^{c}	3.60 ^{a}	11.01 ^{c}	11.73 ^{c}	1.72 ^{c}	1.61 ^{c}	44.47 ^{c}	40.58 ^{b}
Vruckwona Africano	53.50 ^{b}	73.50 ^{b}	3.32 ^{c}	3.60 ^{a}	13.38 ^{c}	10.62 ^{d}	1.47 ^{c}	1.90 ^{c}	50.26 ^{c}	46.50 ^{b}
Cameroon	41.00 ^{b}	52.00 ^{b}	4.23 ^{a}	3.60 ^{a}	17.73 ^{a}	13.85 ^{c}	2.87 ^{a}	2.33 ^{b}	45.97 ^{c}	54.58 a
CPAC	34.50 ^{b}	44.50 ^{b}	3.90 ^{b}	3.40 ^{b}	15.05 ^{b}	13.02 ^{c}	2.66 ^{b}	3.53 ^{a}	60.98 ^{b}	67.51 a
Guacu	43.00 ^{b}	55.00 ^{b}	3.45 ^{c}	3.55 ^{a}	13.91 ^{b}	14.24 ^{b}	2.30 ^{b}	2.25 ^{b}	78.24 ^{a}	60.83 a
Napierzinho	68.00 ^{a}	44.00 ^{b}	3.10 ^{c}	3.10 ^{b}	12.22 ^{c}	9.12 ^{d}	1.33 ^{c}	1.53 ^{c}	52.67 ^{b}	37.08 ^{b}
IJ 7125 cv EMPASC 308	88.50 ^{a}	105.00 ^{a}	2.97 ^{c}	3.45 ^{b}	12.19 ^{c}	12.03 ^{c}	1.45 ^{c}	1.55 ^{c}	40.12 ^{c}	46.13 ^{b}
IJ 7126 cv EMPASC 310	37.00 ^{b}	46.50 ^{b}	3.50 ^{c}	3.90 ^{a}	16.47 ^{a}	17.44 ^{a}	1.28 ^{c}	1.33 ^{c}	39.28 ^{c}	38.24 ^{b}
IJ 7127 cv EMPASC 309	67.00 ^{a}	157.00 ^{a}	3.25 ^{c}	3.00 ^{c}	9.80 ^{c}	10.75 ^{d}	1.42 ^{c}	1.10 ^{c}	45.46 ^{c}	35.50 ^{b}
IJ 7136 cv EMPASC 307	30.00 ^{b}	118.00 ^{a}	3.05 ^{c}	2.70 ^{c}	13.36 ^{c}	12.89 ^{c}	1.60 ^{c}	1.50 ^{c}	50.64 ^{c}	38.00 ^{b}
IJ 7139	51.50 ^{b}	64.00 ^{b}	4.29 ^{a}	3.25 ^{b}	18.58 ^{a}	14.72 ^{b}	3.26 ^{a}	2.56 ^{b}	42.56 ^{c}	55.66 a
IJ 7141 cv EMPASC 306	35.35 ^{b}	44.00 ^{b}	3.40 ^{c}	3.55 ^{a}	14.98 ^{b}	15.08 ^{b}	2.33 ^{b}	1.52 ^{c}	60.88 ^{b}	38.08 ^{b}
Goiano	38.00 ^{b}	62.00 ^{b}	3.60 ^{b}	3.40 ^{b}	15.33 ^{b}	15.06 ^{b}	2.30 ^{b}	1.48 ^{c}	57.29 ^{b}	46.50 ^{b}
CAC-262	95.00 ^{a}	81.50 ^{b}	3.47 ^{c}	3.75 ^{a}	12.27 ^{c}	11.07 ^{d}	1.72 ^{c}	1.53 ^{c}	48.07 ^{c}	41.83 ^{b}
Ibitinema	95.00 ^{a}	119.00 ^{a}	3.05 ^{c}	3.20 ^{b}	10.66 ^{c}	10.90 ^{d}	1.14 ^{c}	1.46 ^{c}	41.82 ^{c}	42.08 ^{b}
903-77 ou Australiano	121.00 ^{a}	168.50 ^{a}	3.22 ^{c}	3.70 ^{a}	11.21 ^{c}	13.28 ^{c}	1.81 ^{c}	1.30 ^{c}	43.59 ^{c}	38.25 ^{b}
13 AD	96.00 ^{a}	132.00 ^{a}	2.95 ^{c}	2.50 ^{d}	10.07 ^{c}	7.85 ^{d}	1.19 ^{c}	1.41 ^{c}	40.54 ^{c}	39.16 ^{b}
10 AD IRI	92.00 ^{a}	100.00 ^{a}	3.30 ^{c}	3.00 ^{c}	12.34 ^{c}	9.59 ^{d}	1.39 ^{c}	1.40 ^{c}	41.48 ^{c}	40.80 ^{b}
07 AD IRI	61.00 ^{b}	45.50 ^{b}	3.35 ^{c}	3.50 ^{b}	14.07 ^{b}	12.12 ^{c}	1.32 ^{c}	1.43 ^{c}	39.19 ^{c}	45.58 ^{b}
Pasto Panamá	52.00 ^{b}	73.50 ^{b}	4.42 ^{a}	4.25 ^{a}	15.38 ^{b}	15.61 ^{b}	1.86 ^{c}	2.02 ^{b}	47.86 ^{c}	54.08 a
BAG – 92	68.50 ^{a}	58.00 ^{b}	2.62 ^{c}	2.90 ^{c}	10.99 ^{c}	8.69 ^{d}	1.11 ^{c}	1.13 ^{c}	30.11 ^{c}	36.33 ^{b}
09 AD IRI	51.50 ^{b}	71.00 ^{b}	3.10 ^{c}	3.52 ^{b}	11.90 ^{c}	12.36 ^{c}	1.70 ^{c}	1.58 ^{c}	47.45 ^{c}	44.78 ^{b}
11 AD IRI	53.00 ^{b}	62.00 ^{b}	3.30 ^{c}	3.40 ^{b}	10.91 ^{c}	11.57 ^{d}	1.67 ^{c}	1.46 ^{c}	40.04 ^{c}	39.91 ^{b}
05 AD IRI	72.00 ^{a}	77.50 ^{b}	3.17 ^{c}	3.50 ^{b}	11.78 ^{c}	10.73 ^{d}	1.58 ^{c}	1.47 ^{c}	49.36 ^{c}	442.78 ^{b}
06 AD IRI	64.00 ^{b}	120.35 ^{a}	3.12 ^{c}	3.15 ^{b}	14.45 ^{b}	10.61 ^{d}	1.92 ^{c}	1.51 ^{c}	39.76 ^{c}	41.33 ^{b}
01 AD iIRI	79.15 ^{a}	70.00 ^{b}	2.92 ^{c}	3.30 ^{b}	11.50 ^{c}	14.41 ^{b}	2.26 ^{b}	1.47 ^{c}	46.75 ^{c}	29.17 ^{b}
04 AD IRI	40.00 ^{b}	76.25 ^{b}	3.05 ^{c}	2.35 ^{d}	12.45 ^{c}	11.34 ^{d}	1.54 ^{c}	1.23 ^{c}	38.62 ^{c}	37.75 ^{b}
13 AD IRI	57.50 ^{b}	50.00 ^{b}	2.75 ^{c}	2.35 ^{d}	9.97 ^{c}	9.20 ^{d}	0.96 ^{c}	1.16 ^{c}	43.37 ^{c}	36.91 ^{b}
03 AD IRI	51.50 ^{b}	54.50 ^{b}	4.12 ^{a}	4.00 ^{a}	16.35 ^{a}	15.64 ^{b}	2.15 ^{c}	1.67 ^{c}	50.41 ^{c}	48.91 a
02 AD IRI	39.50 ^{b}	54.50 ^{b}	4.31 ^{a}	4.25 ^{a}	15.07 ^{b}	15.23 ^{b}	1.93 ^{c}	1.28 ^{c}	55.69 ^{b}	42.33 ^{b}
08 AD IRI	43.50 ^{b}	59.00 ^{b}	2.85 ^{c}	3.40 ^{b}	11.28 ^{c}	9.94 ^{d}	1.72 ^{c}	1.60 ^{c}	35.31 ^{c}	44.43 ^{b}
União	36.50 ^{b}	41.00 ^{b}	3.61 ^{b}	3.45 ^{b}	16.73 ^{a}	13.50 ^{c}	3.30 ^{a}	2.53 ^{b}	73.95 ^{a}	58.58 a
Pesagro Bord	36.00 ^{b}	35.00 ^{b}	3.65 ^{b}	3.30 ^{b}	14.27 ^{b}	15.81 ^{b}	3.63 ^{a}	2.22 ^{b}	67.54 ^{a}	53.88 a
Average	60.26	72.13	3.55	3.57	13.69	13.30	1.97	1.65	47.34	43.62
Standard Errors	2.01	2.96	0.04	0.03	0.18	0.20	0.05	0.04	0.81	0.85

[1/] Means followed by the same letter in the column do not differ by the Scott-Knott test at 5% probability.

genotype Elefante Cachoeira Itapemirim to 27.00 in Albano, averaging 60.26 tillers per linear meter. In cut 2, the genotype with highest tiller production was Australiano, with 168.50 tillers. In contrast, the genotype with lowest tillering was also Albano, with 31.50 tillers. The average number of tillers in cut 2 was 72.14. Both cuts generated two different groups according to the Scott-Knott clustering at 5% probability (Table 6). Rossi (2010) analyzed fifty two genotypes of elephant grass at ten months of age and obtained an average of 44.5 tillers per meter, which is much lower than the average found in our study. Oliveira (2013) also found a much lower value, of 37.18 tillers per meter, evaluating seventy three genotypes of *P. purpureum* for six months. Several studies have also demonstrated a wide range regarding the number of tillers per linear meter. In the study of Oliveira (2013), the range was from 73 to 13 tillers, and Rossi (2010) reported from 102 to 17.2 tillers per meter. The analysis of the number of tillers is an important process, given that this trait is directly proportional to the potential of productivity of the genotype (Daher et al., 2004; Ribeiro et al., 2009). However, a high number of tillers is not always translated into high productivity; in an experiment with 17 genotypes of elephant grass and one hybrid with millet, Xia et al (2010) concluded that the group with the highest productivity had few tillers. According to Silva et al. (2009), tillering is also important because it provides greater soil cover and consequently a lower number of invasive plants. For the HGT variable, in cut 1, the average was 3.55 m, with Cubano Pinda being the tallest (4.56 m) and BAG-92, the shortest (2.62 m). The Scott-Knott clustering (P<0.05) generated three groups in cut 1. Four groups were generated in cut 2, and the tallest genotype reached 4.40 m (Elefante da Colombia), whereas the shortest reached 2.35 m (04 AD IRI), averaging 3.57 m (Table 6).

A similar value to that found in cuts 1 and 2 was reported by Oliveira (2013): 3.36 m, in 73 genotypes at six months of age. In this same study, the tallest genotype was Roxo Botucatu (3.75 m), and the shortest was 13 AD RI (2.78 m). Corroborating the present study, Oliveira et al. (2012) concluded that the genotype with the lowest height was Cubano Pinda, as compared with six other genotypes at seven months of growth. Kannika et al. (2011) also observed that at 12 months of age elephant grass can reach up to 5 m, which is similar to the average found herein. The importance of the plant-height variable in elephant grass is positively correlated with its dry matter yield (Daher et al., 2004; Xia et al., 2010). The results found by De Mello et al. (2002) agree with this assertion, because they found that irrespective of the season of the year, the selection of elephant-grass plants should be based on the dry matter yield, which is related to taller plants. The stem diameter of the plants in cut one averaged 13.70 mm (18.58 to 9.80 mm), with genotypes IJ 7139 and IJ 7127 cv EMPASC 309 showing outstanding values. However, in cut 2, the values varied from 19.29 to 7.85 mm (average 13.30 mm) for genotypes Mercker Pinda México and 13 AD, respectively (Table 6).

In the Scott-Knott mean clustering (P<0.05) for SD, cut 1 presented three groups, whereas four groups represented cut 2. Similar values to those of cuts 1 and 2 were obtained by Oliveira (2013): 12.32 mm, in the dry season, in an evaluation of 73 genotypes at six months old. Oliveira (2012) found the greatest diameter, 21.30, in Camerron-Piracicaba at seven months of age, and Oliveira (2013) mentions BAG-86 as the 6-mo-old genotype of greatest diameter, 22 mm. Both studies found greater diameter values compared with the present study.

De Mello et al. (2002); Daher et al. (2004b) and Xia et al. (2010) have demonstrated that the stem diameter is positively correlated with productivity. Nevertheless, it has also been reported that stem diameter has a negative correlation with the number of tillers, i.e., the number of tillers decreases as the stem becomes thicker (Italiano et al., 2006).

Regarding the LW trait, in cut 1 genotype Pesagro Bord had the highest value, 3.63 cm, whereas 13 AD IRI had the narrowest leaf, with 0.96 cm, and the average LW was 1.97 cm. For cut 2, the average was 1.65, in which genotype Cuba-116 had the highest value, 3.57, and Teresópolis had the lowest width, 0.95 cm. In this trait, both cuts 1 and 2 in the Scott-Knott mean clustering at 5% presented three distinct groups (Table 6). In genotypes at ages under that analyzed in this study, the average leaf-blade with for both rainy and dry seasons was higher than that described in the present study (De Mello et al., 2002; Schneider, 2013).

It should be stressed that leaf blade width is extremely important in the morpho-agronomic characterization of the elephant grass, because it has a high heritability (98%) in breeding programs with elephant-grass clones, and it is also not very affected by environmental changes (Silva et al., 2009).

The leaf blade length in cut 1, by the Scott-Knott mean clustering (P<0.05), generated three distinct groups, wherein the highest value was presented by Guacu (78.24 cm), and the lowest by Mercker Comum (27.11 cm), with an average of 47.34 cm. The Scott-Knott mean clustering at 5% divided cut 2 into two groups, in which the LL varied from 74.00 to 21.90 cm (average 43.62 cm), for the genotypes Guaco/I.Z.2 and Teresópolis, respectively (Table 6). Just as for LW, in leaf blade length, genotypes assessed at an age (two months) before that of the present study revealed higher values: 78.2 and 71.4 cm, for the rainy and dry seasons, respectively, with genotypes Napier SEA and Elefante da Colombia standing out in the rainy season and Elefante de Pinda in the dry season (De Mello et al., 2002). The leaf-blade length is positively correlated with dry matter yield, which demonstrates the importance of LL as a selection criterion in breeding programs (De Mello et al., 2002; Shimoya et al., 2002). Thus, it was possible to notice significant differences between the genotypes that had the highest and lowest measurements in the two periods assessed in the two years under study. The formation of groups in all variables, in the Scott-Knott clustering at 5%, demonstrates that there is a great differentiation of genotypes as to the studied traits (Oliveira, 2013).

There are other methods to evaluate diversity among genotypes, such as the isoenzyme analysis and the ISSR and RAPD markers. By the first analysis, Daher et al. (1997) and Freitas et al. (2000) demonstrated the genetic diversity among the evaluated elephant-grass accessions using isoenzymatic markers. And utilizing ISSR and RAPD markers, Lima et al. (2011) formed five and six groups in 46 genotypes of elephant grass by UPGMA. However, it should be pointed out that these types of analysis have higher costs; thus, in research with little capital available it is more advantageous to evaluate genetic diversity using morphological characters, which is also more practical and less time-demanding. Still, each method has its own importance, and it is preferable that a germplasm collection be as widely studied and characterized as possible so as to give greater support to research and to the collection database (Sudré et al., 2006).

Multivariate analyses

When the set of characters represents qualitatively different variables and there is no correlation among them the univariate variance analysis is the best procedure to be applied. However, when a dataset displays variables that are correlated, it should be assumed that there is multinormality and so a multivariate analysis of the variance should be carried out (Freitas et al., 2005).

For forages, it is indicated to perform a multivariate analysis in addition to the univariate analysis, given that the traits are usually correlated with each other, because they are measured at the same tussock. Moreover, they are expressed in different scales and units of measurement (Freitas et al., 2005).

Genetic divergence

To analyze the discriminatory power of the variables, it is necessary to evaluate their contribution together, using multivariate analyses (Cruz et al., 2004). Thus, in considering the number of genotypes, the assessed variables and the low discrimination between the genotypes, it is important to perform a multivariate analysis, utilizing canonic variables and dissimilarity (Mahalanobis distance) (Schneider, 2013).The accumulated variance of the first two variables corresponded to 64.6457% of the total variance, because much of it was diluted until the 9th principal component, corresponding to 98.4957% of all the variation available at the germplasm collection (Table 7).

According to Cruz and Regazzi (2001), in the first two canonic variables - the concentration of a great proportion of the total variance, in general referred to as above 80% - it is feasible to study the genetic diversity by geometric distances between parents on a scatterplot. However, Barros (1991) and Pereira et al. (1992) report that the distribution of the variance is associated with the nature and number of characters employed in the analysis, which is focused on the first components only when few characters of agronomic interest, or characters from the same group, are evaluated. Accumulated values below 80% in the first two principal components were also found by Daher et al. (1997), Shimoya et al. (2002) and de Oliveira et al. (2006), who obtained 43.94, 50.02 and 35.80%, respectively. By the analysis of the relative importance of the characters in the canonic variables (Table 8), it was found that the characters of least importance, that is, the discard characters, were NT2, with the highest weighting coefficient at CV10 (0.5395), LL2, with the highest weighting coefficient at CV9 (–0.7178), followed by SD1, having the highest weighting coefficient at CV8 (0.7543). LW2, however, was the character of greatest importance, having the highest weighting coefficient at CV1 and CV2 (0.9889 and –0.7770, respectively), followed by HGT2, with the greatest weighting coefficient at CV3 (–0.6814).

In this analysis, the characters of least importance are considered those relatively invariable or that have redundancy, that is, those are represented by other characters or by a combination of characters, in which the correlation is elevated (Cruz and Regazzi, 2001). Thus, the principal component of greatest importance is that which is the combination of the variables, explaining the greater proportion of the total variation of the data; the second, in turn, defines the next greater variation, and so on (Silva and Sbrissia, 2010).

Corroborating this study, Shimoya et al. (2002) observed that stem diameter and the length of the adult average leaf were the traits of least importance. Daher et al. (2000) also corroborates our study, describing the number of tillers per linear meter as a disposable variable. Daher et al. (1997 and 2000) found that among the most important traits that determine genetic divergence among the elephant-grass genotypes are plant height in the dry and rainy seasons and leaf blade width at the base of the third leaf, both agreeing with the present study.

The technique of principal components has the advantage of assessing the importance of each studied character on the total variation available among the studied genotypes, allowing for the discard of the least important, redundant characters because they are already correlated with other variables or because of their

Table 7. Estimates of the variances (eigenvalues, ëj) associated with the canonic variables and respective weighting coefficients (eigenvectors) of ten variables assessed in 85 elephant-grass genotypes.

ëj	Cumulative variance (%)	Variables									
		1	2	3	4	5	6	7	8	9	10
10.8412	50.1484	-0.2064	-0.0644	0.4949	0.1747	0.2378	0.2652	0.3709	0.5326	0.2011	-0.2989
3.1341	64.6457	-0.1336	-0.0496	0.3166	0.4907	-0.0472	0.5054	-0.3689	-0.4082	0.1467	0.2384
1.9232	73.5417	-0.4322	-0.0529	-0.3017	-0.3863	0.3888	0.5290	0.0900	-0.1439	-0.3321	-0.0048
1.3600	79.8326	-0.1779	0.3975	-0.0083	-0.3353	-0.0912	0.0675	0.2008	0.0409	0.5952	0.5373
1.1515	85.1589	0.6071	0.2384	0.1639	-0.0200	0.0976	0.2430	0.5505	-0.3971	-0.1308	-0.0300
0.9528	89.5662	-0.2978	0.1788	0.5825	-0.1086	0.0131	-0.3471	0.0563	-0.0823	-0.5350	0.3340
0.7343	92.9630	0.1170	0.4681	0.2831	-0.4320	-0.1084	0.1713	-0.4941	0.0168	0.0301	-0.4626
0.6388	95.9180	0.1903	-0.1672	0.1527	-0.1289	0.8042	-0.2837	-0.2465	-0.1555	0.2794	0.0753
0.5573	98.4957	-0.3503	-0.3021	0.1575	-0.1975	-0.2183	-0.2187	0.2446	-0.5588	0.3010	-0.4051
0.3252	100.0000	-0.3020	0.6368	-0.2634	0.4611	0.2566	-0.2297	0.0835	-0.1619	0.0257	-0.2624

1 - NT, cut 1; 2 - NT, cut 2 (per linear meter); 3 - HGT, cut 1; 4 - HGT, cut 2 (m); 5 - SD, cut 1; 6 - SD, cut 2 (mm); 7 - LW, cut 1; 8 - LW, cut 2 (cm); 9 - LL, cut 1; 10 - LL, cut 2 (cm).

Table 8. Relative importance of the characters in the canonic variables established by the linear correlation of ten standardized variables in 85 elephant-grass genotypes.

Canonic variable	Weighting associated with:									
	1	2	3	4	5	6	7	8	9	10
CV1	-0.1284	-0.3264	0.6958	0.0501	0.2806	0.2667	0.3462	0.9889	0.2496	-0.5296
CV2	-0.1282	0.1431	0.0590	0.4773	-0.0596	0.5150	-0.4359	-0.7770	0.1330	0.4224
CV3	-0.2010	-0.0598	-0.4534	-0.6814	0.5451	0.5681	0.1818	-0.1364	-0.3586	-0.0086
CV4	-0.5006	0.7014	0.1226	-0.2487	-0.2618	0.0179	0.0560	-0.7585	0.5858	0.9521
CV5	0.6658	0.1942	0.1516	-0.2515	0.1971	0.2694	0.6090	-0.3657	-0.1382	-0.0532
CV6	-0.4771	0.1896	0.4577	-0.1403	0.0476	-0.3458	0.2044	-0.5673	-0.6144	0.5917
CV7	-0.2073	0.5478	0.3100	-0.3576	-0.0728	0.1941	-0.5330	0.6974	0.0824	-0.8197
CV8	0.3616	-0.2236	0.0184	-0.1593	0.7543	-0.3079	-0.3385	-0.2770	0.2941	0.1333
CV9	-0.1343	-0.3729	0.3105	-0.1380	-0.2398	-0.2115	0.1635	0.0106	0.3691	-0.7178
CV10	-0.4720	0.5395	-0.3002	0.4301	0.2831	-0.2246	0.0763	0.2174	0.0561	-0.4648

1 - NT, cut 1; 2 - NT, cut 2 (per linear meter); 3 - HGT, cut 1; 4 - HGT, cut 2 (m); 5 - SD, cut 1; 6 - SD, cut 2 (mm); 7 - LW, cut 1; 8 - LW, cut 2 (cm); 9 - LL, cut 1; 10 - LL, cut 2 (cm).

invariance; this contributes to the reduction of labor, time and the cost expended on the trial (Daher et al., 1997; Cruz and Regazzi, 2001; Guedes et al., 2013).

In the analysis of the canonic variables, the genetic divergence was demonstrated by the two-dimensional scatter plot, which was determined by estimating the scores obtained from the two canonic variables of highest importance, with the

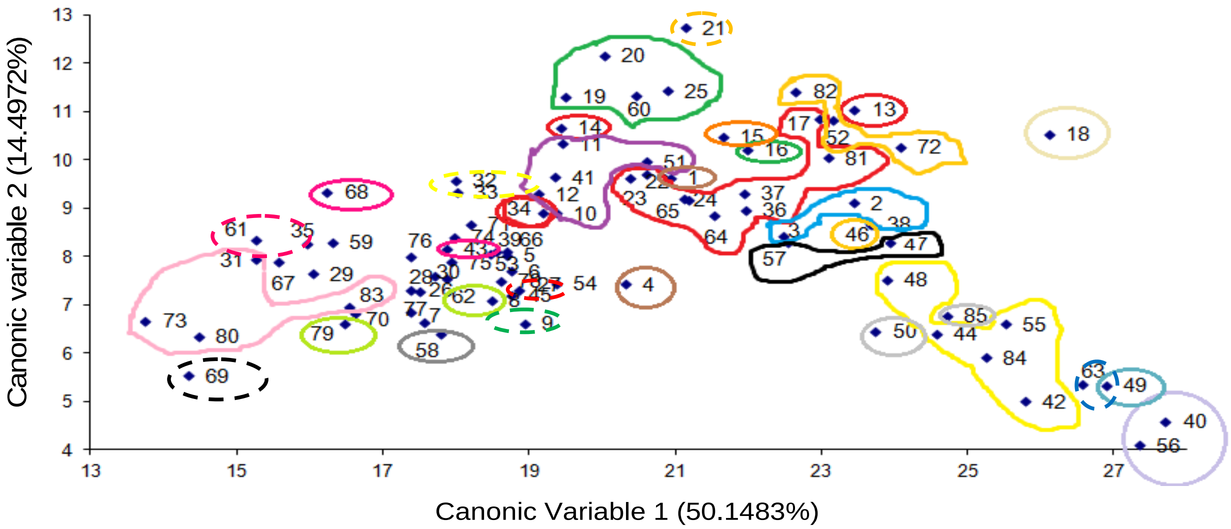

Figure 1. Scatter diagram of 85 genotypes of elephant grass, obtained by the analysis of the first and second canonical variables. Legend: G1 - red; G2 - no color; G3 - yellow; G4 - green; G5 - royal blue; G6 - purple; G7 - light grey; G8 - light pink; G9 - light orange; G10 - light green; G11 - lilac; G12 - dark pink; G13 - dark brown; G14 - black; G15- dark orange; G16 - beige; G17 - ocean blue; G18 - dark grey; G19 - dotted red; G20 - dotted orange; G21 - dotted green; G22 - dotted yellow; G23 - dotted blue; G24 - dotted pink; G25 - dotted black.

X axis being represented by the first canonic variable and the Y axis by the second canonic variable (Figure 1). The distribution of genotypes in the plot is a result of the means with the respective weighting coefficients established in each canonic variable.

The amplitude of the genetic distances coupled with the average of the mean distances of the 85 genotypes indicates a large genetic variability among the studied genotypes (Pereira et al., 2008). This divergence among genotypes was possible by the use of qualitative morpho-agronomic data and multivariate analysis (Sudré et al., 2006).

These results justify the use of analysis of canonic variables, because it simplifies the structure of the original data such that the divergence, at first influenced by a p-dimensional set, is represented in a two-dimensional space, with an easy geometric interpretation (Ferreira et al., 2003). This two-dimensional scattering enabled the separation of the genotypes into groups, and can be utilized as a strategy to select divergent groups to be utilized in future artificial crosses, aiming at genetic improvement (Neitzke et al., 2010).

Tocher's optimization method, shown in Table 9, agreed with the scattering of the genotypes in the two-dimensional graph (Figure 1), because the genotypes belonging to the same group remained close.The analysis of the clusters of the 85 elephant-grass genotypes by Tocher's optimization method based on Mahalanobis distance formed 25 divergent groups (Table 9). The mean distance within the group is the average of the distances between each pair of genotypes that compose it, and this distance is always smaller than the average intergroup distances (Cruz and Regazzi, 2001).

In the analysis, group 2 was composed of the largest number of genotypes, 22, and so the genotypes were subdivided into nine sub-groups. Eleven groups were generated with only one genotype in each one (Table 9).

The genotypes that make up the elite group, described previously (Porto Rico 534-B, Taiwan A-144, Napier S.E.A., Mole de Volta Grande, Teresópolis, Taiwan A-46, Duro de Volta Grande, Turrialba, Taiwan A-146, Cameroon- Piracicaba, Taiwan A-121, P241 Piracicaba, Elefante Cachoeira Itapemirim, Guaco/I.Z.2, Cameroon, IJ 7126 cv EMPASC 310, IJ 7139, Australiano, 10 AD IRI and Pasto Panamá), are in groups 6, 1, 1, 2, 22, 2, 1, 1, 1, 5, 2, 6, 12, 14, 3, 4, 23, 12, 2 and 9, respectively (Table 9). This indicates that possible crosses between pairs of genotypes belonging to different groups result in greater gains with heterosis, due to their dissimilarities. It should be emphasized that the objective of a breeding program is to increase productivity; thus, one should choose genotypes of satisfactory performance that were more divergent or that complement some trait of one of the parents (Ferreira et al., 2003; Guedes et al., 2013). Possible crossings between genotypes of the same group reduce the possibility of obtaining genotypes with different traits (Guedes et al., 2013).

Therefore, the non-involvement of individuals with the same dissimilarity pattern in crosses is suggested, so there will not be genetic variability and hence no negative impacts on the gains to be obtained for selection (Cruz and Regazzi, 2001). Studies on the genetic diversity of elephant grass utilizing Tocher's optimization demonstrate that this method has been well-used, providing a good perspective of the diversity among genotypes and information for future breeding programs based on

Table 9. Analysis of clustering by Tocher's optimization method obtained based on Mahalanobis distance (D^2) for 85 genotypes of elephant grass.

Cluster	Subgroup	Genotypes											
1	-	22	23	24	34	37	36	81	17	65	64	14	13
2	2^a	39	53	45	66	76	30	75	74	26			
2	2^b	29	59	67	70								
2	2^c	89	65										
2	2^d	28	33										
2	2^e	35											
2	2^f	71											
2	2^g	27											
2	2^h	77											
2	2^i	54											
3	-	44	55	42	48	84							
4	-	25	60	20	19	16							
5	-	2	3	38									
6	-	10	12	51	11	41							
7	-	50	85										
8	-	31	73	83	80								
9	-	46	72	52	82								
10	-	62	79										
11	-	40	56										
12	-	43	68										
13	-	1	4										
14	-	47	57										
15	-	15											
16	-	18											
17	-	49											
18	-	58											
19	-	78											
20	-	21											
21	-	7											
22	-	32											
23	-	63											
24	-	61											
25	-	69											

hybridization (Daher et al., 2000, 2002; Shimoya et al., 2002; Pereira et al., 2008).

The number of groups formed by Tocher's method shows the large variability among the genotypes evaluated in this study, demonstrating their broad genetic diversity, which allows for the selection of different parents for breeding programs.

Conclusions

The genotypes that stood out for their dry matter yield were Porto Rico 534-B, Taiwan A-144, Napier S.E.A., Mole de Volta Grande, Teresópolis, Taiwan A-46, Duro de Volta Grande, Turrialba, Taiwan A-146, Cameroon - Piracicaba, Taiwan A-121, P241 Piracicaba, Elefante Cachoeira Itapemirim, Guaco/I.Z.2, Cameroon, IJ 7126 cv EMPASC 310, IJ 7139, Australiano, 10 AD IRI and Pasto Panamá, which composed the elite group. The cluster analysis provided the orientation for crosses involving ten heterotic groups, with the leaf blade width and plant height (cut 2) being the most important to explain the dispersion of genotypes. Tocher's optimization method, associated with Mahalanobis distance, allowed for the clustering of the eighty five genotypes of elephant grass belonging to BAG-CE into twenty five groups.

Conflicts of Interests

The authors have not declared any conflict of interests.

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