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BIOMASS ENERGY PRODUCTION IN ELEPHANT-GRASS HYBRIDS

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Abstract - Elephant grass is a forage plant widely spread in Brazil that was initially employed exclusively in the livestock sector as feed for cattle. This grass is characterized by its high productivity and high photosynthetic capacity. In addition to being used as forage, it has shown to be an alternative source of renewable energy. The objectives of the present study were to evaluate the morpho-agronomic traits of elephant grass hybrids and their parents for biomass energy production. The experiment was conducted in a randomized-block design with three replicates. The partial diallel was composed of 16 hybrids and two groups (males and females). Data were subjected to analysis of variance and the Tukey's mean comparison test ($P < 0.05$). Interaction was detected by the F test for the traits dry matter yield, plant height, and leaf width. Based on the mean values, hybrids H11 and H14 seem to be promising for dry matter production for energy purposes. Parent Porto Rico 534-B can be indicated in breeding programs.

Keywords: Diallel, energy, plant breeding, *Pennisetum purpureum*

Introduction

Elephant grass belongs to the family Poaceae, genus *Pennisetum*. The species, named *Pennisetum purpureum* Schumm, is typical of tropical regions. Literature records date its introduction in the Brazilian territory to around the early 20th century, by Colonel Napier (Bennet, 1976). This forage species has excellent an dry matter yield per cultivated area (Zanine et al., 2007).

At present, it is known that the produced biomass is able to meet the requirements for both forage and energy generation. In addition, this plant has a high genetic variability, which allows it to adapt to different regions of Brazil (Daher et al., 2000; Freitas et al., 2004; Pereira et al., 2008; Vitor et al., 2009; Cruz et al., 2010; Meinerz et al., 2011).

The plants of this species undergo some changes during their growth and development regarding their agronomic, morphological, and biomass-quality traits. Thus, as the plant is developed, its dry matter content is changed (Van Soest, 1994).

According to Dias et al. (2008), in their early life stages, grasses usually have highly digestible nutritional components, and forage intake is high. As the plant develops, its nutritional value is decreased by the dilution of the nutrients, which generates an increase in the proportion of fibrous components. This has a negative effect on the intake of plant material by animals. Additionally, there may be an increase in productivity. All these characteristics are of interest to the energy sector.

Thus, the objective of the study was to evaluate the morpho-agronomic traits of elephant grass hybrids and their parents for biomass energy production.

Materials and methods

The experiment was conducted at Pesagro, located in the municipality of Campos dos Goytacazes - RJ, Brazil (21°19’23’’ S, 41°19’40’’ W, and altitude of 20 to 30 m). The climate of the region is a Köppen’s AW type (tropical with dry winters).

A randomized-block design with three replicates was adopted. The plot consisted of a 4-m row with 1.5-m spacing between rows, in which 1 m was considered floor area within the rows. Each block comprised 25 treatments (16 hybrids, 8 parents and 1 control).

Two groups of elephant-grass parents were evaluated. Group 1 consisted of four male parents: Taiwan A-144 (P1), Vruckwona (P2), Pusa Napier no. 2 (P3), and Porto Rico 534-B (P4). Group 2 had four female parents: Mercker Santa Rita (P1), Taiwan A-146 (P2), Mercker S. E. A. (P3) and Napier no. 2 (P4). Accession BAG-86 was utilized as control. The hybrids were obtained the from diallel crosses shown in Table 1.

Planting was done in May 2010, using stakes arranged with the base of a plant touching the apex of the other plant, distributed into 10-cm-deep furrows. At planting, 100 kg/ha of P_2O_5 (single superphosphate) were applied. After the establishment period, all genotypes were cut near the soil level (plot leveling) in December 2010, and then topsoil fertilization was applied with 25 kg ha^{-1} of ammonium and potassium chloride. An additional planting was performed in the plots in which plant-emergence failures were observed.

Three cuts were made for evaluation: the first, in August 2011 (36 weeks after the plot-leveling cut — dry season); the second, in April 2012 (36 weeks after the first cut — rainy season); and the third cut, in September 2012 (23 weeks after the 2nd cut — dry season).

The following morpho-agronomic traits were evaluated in each cut: plant height (HGT), in m: measured from the soil up to the curvature of the last fully expanded leaf; stem diameter (SD), in mm: measured at 10 cm above the soil level; leaf with (LW), in cm: measured with a graduated ruler and obtained by making three measurements per replicate; and number of tillers (NT), in tillers per linear meter: the count was made in 1.0 m within the rows, discarding the extremities resulting from sprouting failures. A sample was taken to be dried in an oven at 65 ºC for 72 h until reaching a constant weight (air-dried sample - ADS). The dried material (leaf and stem) was ground in a Wiley mill with 1 mm sieve and conditioned in plastic bottles. Next, the samples were dried again in an oven at 105 ºC for 12 h (oven-dried sample - ODS), and then the percentage of dry matter (%DM) of the product between ADS and ODS and the total dry matter yield (DMY), in t ha^{-1}, were determined.

An analysis of variance was performed for each cut based on the average of the plots. Later, a combined analysis of variance of the three cuts was conducted, following a split-plot in time design (Steel and Torrie, 1980). Means were compared by Tukey’s test ($P < 0.05$). The GENES software was utilized for the statistical analysis (Cruz, 2013).

Results

The results of the individual analyses of variance for each cut of the morpho-agronomic traits evaluated in the 1st, 2nd, and 3rd cuts demonstrated significant differences, by the F test ($P < 0.05$), for the trait percentage of dry matter (%DM) in the sources of variation parent and hybrid × parent contrast; for dry matter yield (DMY) in the sources of variation treatment, genotype, and parent; for number of tillers (NT) in the sources of variation genotype, parent, and hybrid × parent contrast; for height (HGT) in the sources of variation hybrid, parent, and the hybrid × parent contrast; and for leaf width (LW), only in the source of variation parents. Furthermore, significant differences were detected by the F test at $P < 0.01$ in the trait NT, only for treatments; in HGT, in the sources of variation treatment and genotype; and in LW, only in the source of variation genotype.

In the 2nd cut, there were significant differences ($P < 0.05$) for the trait %DM in the sources of variation treatment and genotype; for DMY, in the sources of variation treatment, genotype, and parent; for NT, only in the source of variation hybrids; in SD, in the source of variation parent; and in LW, only for the hybrid × parent contrast. Significant differences were also observed ($P < 0.01$) for the trait %DM in the source of variation hybrid; for NT in the sources of variation treatment, genotype, and parent, and in the genotype × control contrast; for HGT in the sources treatment and genotype; and for the trait SD in the sources treatments and genotypes and in the genotype × control contrast, indicating that there is at least one genotypes among the hybrids and/or parents that displayed similar or superior response to the control BAG-86; and in the hybrid × parent contrast, indicating that at least one hybrid was superior to the parents for this trait.

In the 3rd cut, significant differences ($P < 0.05$) were observed in the source of variation treatments for the traits DMY and HGT; in the source of variation genotype, for the trait DMY; in the genotype × control contrast, for the traits DMY and HGT; in the hybrid × parent contrast for the traits SD and LW. Besides, significant differences ($P < 0.01$) occurred for the trait DMY, in the source of variation parent; in the trait HGT, in the source of variation hybrid × parent; for SD, in the source of variation genotype and in the genotype × control contrast; and in LW, in the sources of variation genotype, parent, and hybrid, and in the genotype × control contrast.

In the combined analysis of variance, significant differences were detected, by the F test, between the genotypes for all the evaluated traits, indicating the existence of genetic variability among the treatments. For the traits DMY, HGT, and LW, an interaction between genotype and cut was present ($P < 0.01$), indicating that the genotypes' response is not consistent throughout the cuts, i.e., there are differences between the genotypes means or in the classification of their performance, over different cuts.

The comparisons between the means for traits DMY and %DM in the hybrids originating from partial diallel crosses, according to Tukey's test ($P < 0.05$), are described in Table 2.

It was found that, for the 1st cut, the average DMY varied from 26.31 t ha^{-1}, in hybrid H14, to 6.18 t ha^{-1}, in parent Mercker Santa Rita. Also, only these genotypes were statistically different.

In the 2nd evaluation cut, a significant difference was only found between parent Porto Rico 534-B and hybrid H10. Genotypes H1, H4, H6, H11, Taiwan A-144, Porto Rico 534-B, Taiwan A-146, and BAG-86 obtained the highest mean values, so they can be used in breeding programs as energy sources, especially given their high DMY. In the 3rd cut, the mean ranged from 23.39 t ha^{-1}, in Vruckwona, to 5.77 t ha^{-1}, in Pusa Napier no. 2, and significant differences only occurred between the genotypes Vruckwona, which averaged 23.98 t ha^{-1}, and BAG-86, with 19.48 t ha^{-1}.

Regarding the trait %DM, it was observed that, in the 1st cut, the mean values of the genotypes varied between 44.15%, in hybrid H14, and 31.94%, in genotypes Pusa Napier no. 2 and Mercker Santa Rita. For the 2nd and 3rd cuts, the genotypes' response did not differ. In the 2nd cut, the mean ranged from 40.71, in hybrid H6, to 32.21%, in hybrid H13. In the 3rd cut, it varied between 39.23%, in hybrid H14, and 32%, in hybrid H10. No significant differences were detected between the three cuts for the genotypes. In general, analyzing the three cuts, only hybrids H10, H12, and H14 differed between the cuts.

The comparisons between the mean values of traits HGT and SD in the hybrids resulting from partial diallel crosses, according to Tukey's test ($P < 0.05$), are described in Table 3.

For the trait HGT, in the 1st cut, the mean ranged from 4.00 m, in parent Pusa Napier no. 2, to 3.06 m, in hybrid H10. Hybrids H5 and H10, with mean values of 3.13 m and 3.06 m, respectively, differed from genotypes Pusa Napier no. 2 and Porto Rico 534-B, which averaged 4.00 m and 3.93 m, respectively, standing out for having the highest values. In the 2nd cut, the mean varied between 4.10 and 3.23 m. In this cut, genotypes Taiwan A-144, with a mean value of 4.10 m, and Porto Rico 534-B, with 4.03 m, differed statistically from hybrid H10, which averaged 3.23 m. No differences between the genotypes were detected in this cut. Moreover, analyzing the mean response of the genotypes in the three successive cuts, hybrid H9 was the only one that did not differ between the three cuts. In contrast, genotypes H11, H14, Taiwan A-144, Vruckwona, Porto Rico 534-B, Mercker Santa Rita, and BAG-86 displayed the highest mean values among the three cuts.

In the case of the trait SD, the groups were divided and the threshold values of this trait were observed. In the 1st cut, the mean varied from 12.00 mm, in H12, to 8.89 mm, in H10, with no differences detected between the genotypes. In the 2nd cut, the mean ranged from 18.47 mm, in BAG-86, to 11.58 mm, in H6. Hybrids H1, H4, H5, H7, H8, H9, H12, H13, H14, H15, and H16 and all parents stood out, except for Mercker S. E. A. and the control, whose means did not differ. In the 3rd cut, the mean ranged from 16.42 mm, in BAG-86, to 8.51 mm, in H6. Differences were detected between the genotypes, as follows: H1 (8.79 mm), H4 (9.99 mm) H6 (8.51 mm), H9 (9.21mm), H10 (10.36 mm), H11 (10.26 mm), H13 (10.53 mm), H14 (10.57 mm), H15 (10.34 mm), and Mercker Santa Rita (10.35 mm).

The comparisons of the mean values for the traits LW and NT in the hybrids resulting from the partial diallel crosses, according to Tukey's test ($P < 0.05$), are described in Table 4.

In LW, the observed mean was 2.50 cm. The mean value for this trait ranged from 3.76 cm, in genotype BAG-86 (control), to 1.33 cm, in hybrid H9, in the 1st cut. In genotypes H10, H14, Vruckwona, Mercker Santa Rita and BAG-86, the mean values differed statistically from each other. In the 2nd cut, all genotypes had mean values higher than those of the 1st cut, ranging from 4.91, in BAG-86, to 3.10 cm, in H13. No differences were detected between the mean values of genotypes H11 (3.73 cm), H14 (4.04 cm), Taiwan A-144 (3.69 cm), Vruckwona (3.99 cm), Porto Rico 534-B (3.73 cm), Mercker Santa Rita (3.82 cm), Mercker S. E. A. (3.81 cm), and BAG-86 (4.91 cm). In the 3rd cut, the mean varied from 3.36 cm, in BAG-86, to 1.13 cm, in H4. For this cut, hybrids H3, H5, H10, and H11, parent Vruckwona, and the control (BAG-86) showed the highest values and did not differ from each other.

In the 1st cut, the mean for the trait NT varied from 42.66 tillers.m^{-1}, in hybrids H11 and H14, to 15.56 tillers.m^{-1}, in parent Pusa Napier no. 2. Genotypes H11, H14, Taiwan A-144, and Pusa Napier no. 2 were statistically different. In the 2nd cut, the mean varied from 51.33 tillers.m^{-1}, in H1 to 17.0 tillers.m^{-1}, in parent Pusa Napier no. 2. The genotypes showed values very close to each other, except for genotypes H1, H11, Porto Rico 534-B, and Pusa Napier no. 2, which differed from each other in their mean values. In the 3rd cut, the mean variation was of 82.66 tillers.m^{-1}, in H12, to 36.16 tillers.m^{-1}, in BAG-86. In this cut, no statistical differences were detected between the evaluated genotypes. In addition, the genotypes that had a stable behavior, without influences from the cut, were H11, H13, H14, Vruckwona, and Porto Rico 534-B.

Discussion

Higher DMY values could be expected from the genotypes evaluated in the present study, since Santos et al. (2014) evaluated genotypes Guaçu/IZ.2, Cameroon-Piracicaba, and Capim Cana D'África in three cuts and obtained mean values of 29, 63, and 32.91 t ha^{-1} in the 1st cut applying 500 kg ha^{-1} N as fertilizer, i.e., higher DMY under nitrogen fertilization. Evaluating the total dry matter yield of cultivar Roxo at different cutting ages, Queiroz Filho et al. (2000) obtained an average of 30.9 t ha^{-1} at 100 days. Morais et al. (2009), evaluating five genotypes of elephant grass intended for bioenergy production, obtained mean values of 45 t ha^{-1} to 67 t ha^{-1} for dry matter yield. Flores et al. (2013) studied the performance of genotypes Paraíso and Roxo for biomass production for energy uses in the soil-climatic conditions of the Cerrado biome and obtained mean values higher than 30 t ha^{-1}, irrespective of the use of fertilizers. Andreoli (2008), however, stated that with little use of inputs and investments, the dry matter yield generated by the elephant-grass biomass might reach around 20 to 25 t ha^{-1}. According to Menezes et al. (2016), evaluating ten genotypes of elephantgrass in partial diallel, the Mercker and Taiwan A-144 genotypes were among those with the highest yields of 19.76 and 18.57 t ha^{-1}, respectively.

The %DM in the winter is higher and lower in the summer period (Meinerz et al., 2008). Greater accumulation of DM by the elephant grass for energy purposes is desirable because of the higher cellulose, fiber, and lignin contents. However, with the exception of hybrids H10 and H13, which showed a downward trend for %DM in the 3rd evaluation cut, the genotypes showed a significantly similar %DM in the three evaluation cuts. Rossi et al. (2014) evaluated the canonical correlations between morphological and biomass-quality traits in forty genotypes of elephant grass for production of energy and observed an overall mean of 37.15% for %DM, which is close to that found in the present study.

The HGT values agree with those found by Oliveira et al. (2014), who observed mean values varying from 3.02 to 4.40 m in elephant-grass genotypes for biomass energy production. In the 3rd cut, the mean varied from 3.05 m, in Porto Rico 534-B, to 2.13 m, in hybrid H4. According to Xia et al. (2010), this trait is positively correlated with dry matter yield.

Evaluating the emergence of 73 genotypes of elephant grass, Oliveira et al. (2013) observed that eight weeks after planting the genotypes already had an overall mean of 14.25 mm, i.e., the SD after this period was slightly altered throughout the growth period. The stem diameter is an important trait because, in addition to having a positive correlation with dry matter yield (Xia et al., 2010), it has a direct effect on this trait (Daher et al., 2004).

The mean value of NT was 4.64 tillers m^{-1}, which is higher than the results found in the studies of Pereira et al. (2006) and Silva et al. (2010).

Overall, in this study, the best hybrids were those that showed the highest mean values for the majority of the traits, with steady performance throughout the cuts, given that it is interesting not only for the producer, but also for the companies that want to adopt this plant as raw material for energy generation that the genotypes have a more consistent performance throughout the cuts. Thus, the best hybrids should be identified according to the mean values obtained in the combined analysis. Therefore, it can be asserted that hybrids H11, H13, and H14 stood out for displaying favorable performance in the three cuts.

Table 1. Partial diallel crosses with eight parents and sixteen hybrids of elephant grass.

Group 2 (female parents)	Group 1 (male parents)			
	Taiwan A-144 (P1)	Vruckwona (P2)	Pusa Napier nº 2 (P3)	Porto Rico 534-B (P4)
Mercker Santa Rita (P1)	H1	H5	H9	H13
Taiwan A-146 (P2)	H2	H6	H10	H14
Mercker S. E. A. (P3)	H3	H7	H11	H15
Napier nº 2 (P4)	H4	H8	H12	H16

Table 2. Production and percentage of dry matter of sixteen hybrids and eight parents in the three evaluation cuts. Campos dos Goytacazes - RJ. 2011/2012.

Genotypes / Cut	Traits [1]					
	DMY			%DM		
	1st	2nd	3rd	1st	2nd	3rd
H1	15.62 ab B	44.72 ab A	14.38 ab B	40.97 a A	38.93 a A	38.21 a A
H2	13.79 ab A	23.08 ab A	11.34 ab A	39.00 a A	35.94 a A	36.90 a A
H3	14.85 ab A	23.53 ab A	13.25 ab A	40.96 a A	38.84 a A	37.57 a A
H4	15.14 ab B	41.23 ab A	11.60 ab B	40.99 a A	38.40 a A	35.29 a A
H5	13.08 ab B	31.54 ab A	9.22 ab B	40.05 a A	36.32 a A	33.27 a A
H6	16.97 ab B	53.86 ab A	13.16 ab B	40.85 a A	40.71 a A	37.43 a A
H7	19.25 ab B	35.93 ab A	13.63 ab B	37.03 a A	32.61 a A	32.64 a A
H8	13.94 ab AB	26.67 ab A	10.50 ab B	41.29 a A	38.09 a A	37.41 a A
H9	15.64 ab AB	25.44 ab A	8.83 ab B	41.87 a A	36.07 a A	37.42 a A
H10	12.71 ab A	17.64 b A	7.03 ab A	40.44 a A	34.40 a AB	32.00 a B
H11	18.71 ab B	41.63 ab A	18.47 ab B	42.74 a A	38.80 a A	37.81 a A
H12	17.73 ab A	25.93 ab A	12.79 ab A	41.94 a A	36.08 a AB	34.54 a B
H13	17.53 ab A	37.72 ab A	16.74 ab B	33.89 a A	32.21 a A	35.28 a A
H14	26.31 a AB	37.72 ab A	16.74 ab B	33.89 a A	32.21 a A	35.28 a AB
H15	16.52 ab B	32.96 ab A	12.53 ab B	40.44 a A	37.49 a A	35.94 a A
H16	16.75 ab B	34.61 ab A	13.16 ab B	42.46 a A	39.37 a A	35.94 a A
Taiwan A-144	11.02 ab B	43.65 ab A	15.49 ab B	38.96 a A	35.37 a A	38.27 a A
Vruckwona	20.23 ab A	30.05 ab A	23.98 a A	40.76 a A	34.04 a A	39.35 a A
Pusa Napier nº 2	12.53 ab B	28.81 ab A	5.77 b B	31.94 a A	35.68 a A	37.06 a A
Porto Rico 534-B	20.24 ab B	61.58 a A	18.39 ab B	41.20 a A	39.26 a A	38.00 a A
Mercker Santa Rita	6.18 b B	30.92 ab A	11.08 ab B	31.94 a A	37.69 a A	34.91 a A
Taiwan A-146	18.25 ab B	42.32 ab A	12.51 ab B	37.29 a A	35.57 a A	35.85 a A
Mercker S.E.A.	16.46 ab B	30.33 ab A	9.00 ab B	40.05 a A	38.84 a A	35.01 a A
Napier nº 2	14.22 ab AB	25.95 ab A	9.73 ab B	42.35 a A	36.45 a A	38.26 a A
BAG-86	21.19 ab AB	33.37 ab A	19.48 a B	40.06 a A	36.95 a A	38.30 a A

[1] DMY: dry matter yield, t.ha^{-1}; %DM: percentage of dry matter. Means followed by the same uppercase and lowercase horizontally vertically do not differ by Tukey test ($p<0.05$).

Table 3. Plant height and stem diameter of sixteen hybrids and eight parents in the three evaluation cuts. Campos dos Goytacazes - RJ. 2011/2012.

Genotypes / Cut	Traits[1/]					
	HTG			SD		
	1st	2nd	3rd	1st	2nd	3rd
H1	3.73 ab A	3.90 ab A	2.56 a B	9.77 a B	13.42 abc A	8.79 b B
H2	3.33 ab A	3.65 ab A	2.51 a B	9.66 a A	12.91 bc A	11.17 ab A
H3	3.53 ab A	3.66 ab A	2.51 a B	10.89 a A	13.19 bc A	10.77 ab A
H4	3.65 ab A	3.85 ab A	2.13 a B	9.66 a B	14.80 abc A	9.99 b B
H5	3.13 b A	3.46 ab A	2.43 a B	9.44 a B	13.27 abc A	11.46 ab AB
H6	3.58 ab A	3.90 ab A	2.63 a B	9.11 a A	11.58 c A	8.51 b B
H7	3.61 ab A	3.81 ab A	2.53 a B	11.99 a B	16.04 abc A	11.02 ab B
H8	3.45 ab A	3.70 ab A	2.58 a B	9.55 a B	14.24 abc A	11.03 ab AB
H9	3.46 ab A	3.63 ab A	2.31 a A	10.22 a AB	13.17 abc A	9.21 b B
H10	3.06 b A	3.23 b A	2.53 a B	8.89 a B	12.85 bc A	10.36 b AB
H11	3.50 ab A	3.73 ab A	2.83 a B	9.11 a B	12.57 bc A	10.26 b AB
H12	3.36 ab A	3.75 ab A	2.31 a B	12.00 a A	13.36 abc A	11.00 ab A
H13	3.71 ab A	3.93 ab A	2.66 a B	8.99 a B	15.44 abc A	10.53 b B
H14	3.61 ab A	3.61 ab A	2.91 a B	9.89 a B	13.48 abc A	10.57 b AB
H15	3.48 ab A	3.70 ab A	2.53 a B	9.94 a B	13.60 abc A	10.34 b AB
H16	3.65 ab A	3.89 ab A	2.66 a B	10.44 a B	14.27 abc A	10.85 ab B
Taiwan A-144	3.66 ab B	4.10 a A	2.95 a C	10.33 aB	14.54 abcA	11.07 ab B
Vruckwona	3.61 ab A	3.75 ab A	2.91 a B	11.11 a B	15.29 abc A	12.93 ab AB
Pusa Napier nº 2	4.00 a A	3.76 ab A	2.73 a B	11.44 a B	17.54 ab A	12.57 ab B
Porto Rico 534-B	3.93 a A	4.03 a A	3.05 a B	11.77 a B	16.95 abc A	11.68 ab B
Mercker Santa Rita	3.50 ab A	3.31 ab A	2.83 a B	9.00 a B	15.76 abc A	10.35 b B
Taiwan A-146	3.70 ab A	4.00 ab A	2.63 a B	11.22 a B	15.57 abc A	11.71 ab B
Mercker S.E.A.	3.43 ab A	3.58 ab A	2.61 a B	9.77 a A	12.87 bc A	10.57 b A
Napier nº 2	3.41 ab A	3.73 ab A	2.40 a B	10.66 a AB	13.49 abc A	9.86 b B
BAG-86	3.45 ab A	3.66 ab A	3.00 a B	11.44 a B	18.47 a A	16.42 a A

[1/] HGT: plant height, m; DC: stem diameter, mm. Means followed by the same uppercase and lowercase horizontally vertically do not differ by Tukey test ($p<0.05$).

Table 4. Leaf with and number of tillers of sixteen hybrids and eight parents in the three evaluation cuts. Campos dos Goytacazes - RJ. 2011/2012.

Genotypes / Cut	Traits[1/]					
	LW			NT		
	1st	2nd	3rd	1st	2nd	3rd
H1	1.53 b B	3.43 b A	1.96 bcdef B	37.66 ab B	51.33 a AB	61.33 a A
H2	1.73 b B	3.26 b A	2.26 bcde B	29.66 ab A	32.0 ab A	46.66 a A
H3	1.70 b B	3.32 b A	2.36 abcde B	36.0 ab B	46.0 ab A	66.66 a A
H4	1.76 b B	3.56 b A	1.13 f B	28.66 ab B	35.33 ab B	75.33 a A
H5	1.86 b C	3.41 b A	2.56 abc B	32.0 ab A	38.33 ab A	50.0 a A
H6	1.60 b B	3.20 b A	1.86 cdef B	39.0 ab B	45.66 ab B	75.6 a A
H7	1.63 b B	3.36 b A	1.7 cdef B	34.0 ab B	26.33 ab B	64.66 a A
H8	1.40 b C	3.51 b A	2.26 bcde B	28.66 ab B	34.0 ab B	53.66 a A
H9	1.33 b B	3.27 b A	2.03 bcdef B	36.0 ab A	36.66 ab A	46.66 a A
H10	2.36 ab B	3.51 b A	2.5 abcd B	32.33 ab A	31.66 ab A	37.33 a A
H11	1.80 b B	3.73 ab A	2.4 abcde B	42.66 a A	48.0 a A	57.1 a A
H12	1.46 b B	3.18 b A	1.43 ef B	34.0 ab B	41.0 ab B	82.66 a A
H13	1.63 b B	3.10 b A	1.76 cdef B	37.66 ab B	42.33 ab B	62.0 a A
H14	2.76 ab B	4.04 ab A	1.86 cdef C	42.66 a A	29.0 ab A	46.66 a A
H15	1.76 b B	3.42 b A	2.03 bcdef B	34.66 ab B	38.33 ab B	58.4 a A
H16	1.83 b B	3.59 b A	2.13 bcdef B	36.66 ab B	40.33 ab B	61.33 a A
Taiwan A-144	1.46 b B	3.69 ab A	1.96 bcdef B	16.0 b B	32.66 ab AB	48.0 a A
Vruckwona	2.60 ab B	3.99 ab A	2.93 ab B	31.0 ab A	44.0 ab A	49.66 a A
Pusa Napier nº 2	1.36 b B	3.37 b A	1.6 cdef B	15.66 b B	17.0 b B	42.33 a A
Porto Rico 534-B	1.60 b B	3.73 ab A	1.50 def B	36.0 ab B	47.33 a AB	64.33 a A
Mercker Santa Rita	2.83 ab B	3.82 ab A	2.03 bcdef C	30.66 ab B	36.0 ab AB	52.33 a A
Taiwan A-146	1.96 b B	3.44 b A	1.43 ef B	30.0 ab B	37.66 ab AB	52.43 a A
Mercker S.E.A.	1.93 b B	3.81 ab A	2.2 bcde B	34.0 ab A	34.33 ab A	51.0 a A
Napier nº 2	1.60 b C	3.58 b A	2.3 bcde B	29.66 ab B	30.66 ab B	53.0 a A
BAG-86	3.76 a B	4.91 a A	3.36 a B	25.0 ab A	22.33 ab A	36.16 a A

[1/] LW: leaf with, cm; NT: number of tillers. Means followed by the same uppercase and lowercase horizontally vertically do not differ by Tukey test ($p<0.05$).

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