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de Andrade Gimenes, Flávia Maria; Berndt, Alexandre; Pavan Mateus, Gustavo; da Silva Lédo, Francisco José; Assumpção de Abreu Demarchi, João José; Giacomini, Alessandra Aparecida; Gerdes, Luciana; Batista, Karina

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Forage mass and agronomic traits of Elephant grass genotypes under free-growth and conventional cutting systems

Massa de forragem e características agronômicas de genótipos de capim Elefante submetidos a sistemas de crescimento livre e corte convencional

Flávia Maria de Andrade Gimenes[1*]; Alexandre Berndt[2]; Gustavo Pavan Mateus[3]; Francisco José da Silva Lédo[4]; João José Assumpção de Abreu Demarchi[1]; Alessandra Aparecida Giacomini[1]; Luciana Gerdes[1]; Karina Batista[1]

Abstract

Few grass genotypes with high yield potential are used as fodder in Brazil, making it necessary to develop new cultivars. In this study, we compared tiller density, forage mass, and agronomic traits across 12 Elephant grass (*Pennisetum purpureum* Schum.) genotypes under free-growth and conventional cutting systems at the Agência Paulista de Técnologia dos Agronegócios (APTA), Andradina, São Paulo, Brazil. The experimental design of the two trials was three replicates of a randomized complete block, each experimental unit consisting of 37.5 m^2 plots with five rows spaced 1.5 m apart. We estimated tiller density 30, 60, and 150 days after planting (DAP), and 90 days after cut (DAC), and harvested the grass 150 DAP and 90 DAC for determination of forage mass and agronomic traits. In the free-growth system, forage mass was highest in genotypes CNPGL 00-155-2, CNPGL 92-41-1, CNPGL 92-51-1, and CNPGL 96-21-1 and in cultivar Guaçu. After cutting and regrowth, forage mass was highest in genotypes CNPGL 93-41-1, CNPGL 92-41-1, and CNPGL 91-11-2 and in cultivars Mineiro IPEACO, Guaçu, and Pioneiro. Stem mass was higher than leaf mass in the two trials, with leaf/stem ratio in most genotypes below 1.0. Aerial tiller density was highest for genotypes Pioneiro and CNPGL 00-155-2, and stem diameter was smallest in cv. Pioneiro in the free-growth and in the cutting and regrowth systems (9.7 and 7.62 mm, respectively). After regrowth, plant height ranged from 0.56 m in cv. Guaçu to 2.0 m in cv. Mineiro IPEACO and the mean number of internodes.$stem^{-1}$ ranged from 2.1 in cv. Guaçu to 7.4 in cv. Pioneiro. Forage mass correlated positively with basal tiller density ($r = 0.4096$) and negatively with stem diameter ($r = -0.4879$) in the free-growth trial, but relationships were not significant after regrowth.
Key words: Height. *Pennisetum purpureum*. Tiller density. Clones. Hybrids. Leaf/stem ratio.

Resumo

Poucos genótipos de capim com alto potencial produtivo são utilizadas como forragem no Brasil, tornando-se necessário o desenvolvimento de novos cultivares. Neste estudo, foram comparadas

[1] Pesquisadores Científicos, Instituto de Zootecnia, IZ, Nova Odessa, SP, Brasil. E-mail: flavia@iz.sp.gov.br; demarchi@iz.sp.gov.br; giacomini@iz.sp.gov.br; lgerdes@iz.sp.gov.br; karina@iz.sp.gov.br

[2] Pesquisador, Empresa Brasileira de Pesquisa Agropecuária, EMBRAPA Pecuária Sudeste, São Carlos, SP, Brasil. E-mail: alexandre.berndt@embrapa.com.br

[3] Pesquisador Científico, Agência Paulista de Tecnologia dos Agronegócios, APTA, Andradina, SP, Brasil. E-mail: gpmateus@apta.sp.gov.br

[4] Pesquisador, EMBRAPA Gado de Leite, Juiz de Fora, MG, Brasil. E-mail: francisco.ledo@embrapa.br

* Author for correspondence

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densidade de perfilhos, massa de forragem e características agronômicas em 12 genótipos de capim Elefante (*Pennisetum purpureum* Schum.) sob sistemas de crescimento livre e corte convencional na Agência Paulista de Tecnologia dos Agronegócios (APTA), Andradina, São Paulo, Brasil. O delineamento experimental dos dois experimentos foi três repetições de blocos casualizados, cada unidade experimental que consistiu em parcelas de 37,5 m^2, com cinco linhas espaçadas de 1,5 m de distância. Foram estimamos a densidade de perfilhos aos 30, 60 e 150 dias após o plantio (DAP), e 90 dias após o corte (DAC), e colhidas a a forragem 150 DAP e 90 DAC para a determinação da massa de forragem e características agronômicas. No sistema de livre crescimento, massa de forragem foi maior nos genótipos CNPGL 00-155-2, CNPGL 92-41-1, CNPGL 92-51-1 e 96-21-1 CNPGL e no cultivar Guaçu. Após o corte e rebrota, a massa de forragem foi maior nos genótipos CNPGL 93-41-1, CNPGL 92-41-1 e 91-11-2 CNPGL e nos cultivares Mineiro IPEACO, Guaçu, e Pioneiro. A massa de colmos foi maior do que a massa foliar nos dois experimentos, com relação folha /colmo na maioria dos genótipos inferior a 1,0. Densidade de perfilhos aéreos foi maior para genótipos Pioneiro e CNPGL 00-155-2, e diâmetro do caule foi menor no cv. Pioneiro nos sistemas de crescimento livre e de corte e rebrota (9,7 e 7,62 mm, respectivamente). Depois da rebrotação, a altura da planta variou de 0,56 m na cv. Guaçu a 2,0 m na cv. Mineiro IPEACO e o número médio de internodes do colmo variou de 2,1 em cv. Guaçu para 7,4 em cv. Pioneiro. A massa de forragem foi positivamente correlacionada com a densidade de perfilhos basais (r = 0,4096) e negativamente com diâmetro do caule (r = -0,4879) no experimento de crescimento livre, mas as relações não foram significativas após a rebrotação.

Palavras-chave: Altura. Clones. Densidade de perfilhos. Híbridos. *Pennisetum purpureum*. Relação folha/colmo.

Introduction

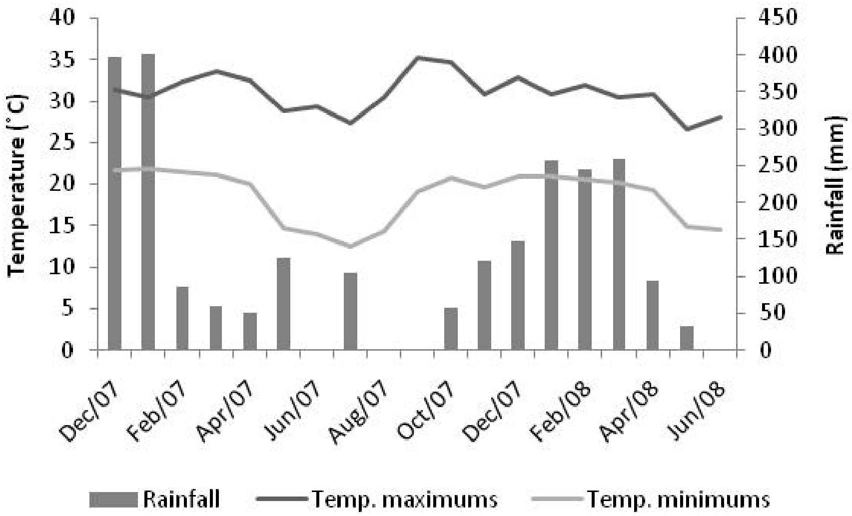
Grass species are the main source of fodder for dairy farming in Brazil, warranting the use of improved cultivars to increase milk production. Elephant grass (*Pennisetum purpureum* Schum.) is one of the main fodder species used in Brazil for animal feeding as fresh chopped fodder or stored fodder in the form of silage or hay, especially in dairy farms. This species produces up to 80.0 $kg.ha^{-1}$.year of palatable and highly nutritional forage (FARIA et al., 1996; OLIVO et al., 2013; LEÃO et al., 2012; SARAIVA, KONIG, 2013). Despite the various possible uses of Elephant grass, Valle et al. (2003) warned about the low genetic diversity of cultivated pastures in Brazil, where only two genera (*Panicum* and *Brachiaria*) amount to 85% of all seeds marketed, consisting mainly of apomictic materials. Thus, the evaluation of new forage genotypes is essential for releasing new cultivars on the market.

The optimal use of forage species requires a thorough understanding of the growth patterns of different cultivars under different management systems, which directly affect the morphogenic and structural characteristics, and the growth and senescence processes, of forage plant tissues (RODOLFO et al., 2015). However, little is known about the tillering patterns, yield components, and forage quality of new Elephant grass cultivars. This study aimed to correct this gap, by comparing tiller density, forage mass, and agronomic traits across 12 Elephant grass genotypes under free-growth and conventional cutting systems.

Materials and Methods

The trials were set up at the Pólo Regional Extremo Oeste da Agência Paulista de Tecnologia dos Agronegócios (APTA) in Andradina, São Paulo, Brazil (20°53’ S and 51°22’ W, 368 m elevation). The climate is humid tropical (Aw) according to the Köppen classification, with a rainy season in summer and a dry season in winter (Figure 1). The soil in the experimental area is typical dystrophic medium texture red latosol (SANTOS et al., 2006). Soil properties at 0–20 cm were, pH $CaCl_2$: 4.8; organic matter: 23.0 $g.L^{-1}$; phosphorus (P): 5.0 $mg.L^{-1}$; calcium (Ca): 12.0 $mmol_c.L^{-1}$; magnesium (Mg): 4.0 $mmol_c.L^{-1}$; potassium (K): 2.0 $mmol_c.L^{-1}$; cation exchange capacity (CEC): 43.0 $mmol_c.L^{-1}$; and base saturation (V%): 42%. Dolomitic limestone (1.5 $t.ha^{-1}$) was applied in August 2006 before planting and single superphosphate (100 $kg.ha^{-1}$ P_2O_5) was applied in furrows in December 2006. Ammonium sulfate was used as the sole nitrogen source and was applied in a single dose at a rate of 50 $kg.ha^{-1}$ N 60 days after planting (DAP).

Figure 1. Monthly average minimum and maximum temperatures (°C) and rainfall (mm) from December 2006 to June 2008.



Seedlings of Elephant grass were planted on December 18–20, 2006. The first trial (free-growth system) was conducted between December 18, 2006 and May 25, 2007 and the second trial (cutting and regrowth) was conducted between March 05 and June 03, 2008. Two cuts were conducted between the experiments (December 2007 and March 2008) using a harvester and the forage harvested was chopped and spread in the area to improve soil quality.

Trial 1: free-growth system

In this trial, grass genotypes were grown in a free-growth system. Because we tested grass genotypes of different morphology and growth habits that may respond differently to cutting frequency, the plants were cut when 50% of all genotypes had flowered (May 22–25, 2007) to standardize the analyses.

Trial 2: cutting and regrowth

In this trial, the plants were harvested 90 days after a standardization cut performed on March 03–05, 2008, using a harvester (Robust RDR Series 00/6, Menta Maquinas Agricolas, Cajuru, SP, Brazil). This cutting frequency combines high yield, even under low-nutrient conditions, and moderate nutritional value (SANTOS et al., 2001).

In the two trials, we evaluated nine new genotypes of Elephant grass (*Pennisetum purpureum* Schum.) (CNPGL 00-155-2, CNPGL 91-02-5, CNPGL 91-11-2, CNPGL 92-41-1, CNPGL 92-51-1, CNPGL 92-79-2, CNPGL 93-41-1, CNPGL 96-24-1, and CNPGL 96-25-3) provided by the Elephant grass breeding program at EMBRAPA Dairy Cattle, and three Elephant grass cultivars (Guaçu, Pioneiro, and Mineiro IPEACO), totaling 12 treatments. Clone CNPGL 00-155-2 is an interspecific triploid hybrid produced from a cross between *P. purpureum* and

P. glaucum (millet); the cv. Mineiro IPEACO is an accession (BAG 66) from the Elephant Grass Active Germplasm Bank (BAGCE) at EMBRAPA Dairy Cattle, whereas the remaining genotypes are intraspecific tetraploid hybrids of *P. purpureum* developed by EMBRAPA. The cultivar Guaçu was provided by the Forage Breeding Program at the Instituto de Zootecnia (IZ), Nova Odessa, São Paulo. The experimental design was three replicates of a randomized complete block, with plot the experimental unit for genotype, each plot consisting of five 5 m long rows spaced 1.5 m apart.

In the two trials, plants were harvested at an approximate cutting height of 10 cm from soil using a machete from the second, third, and fourth rows of each plot. The plant material from each row was tied into a bundle and taken to the laboratory, where it was weighed, chopped in a stationary chopper, sub-sampled, and pre-dried in a forced air circulation oven at 65 °C for 72 h (MELO et al., 2002; RODRIGUES, 2010) for determination of forage dry matter yield. Forage mass was based on the dry matter yield of 12 linear meters (three rows harvested), expressed as kg.ha^{-1} DM.

In the laboratory we randomly selected 10 plants from the grass bundle of the second row of each plot to determine plant height, stem diameter, number of internodes, and leaf/stem ratio. Plant (stem) height was measured from the cutting point to the insertion point of the last expanded leaf using a tape measure. The number of internodes was counted and stem diameter was measured with a caliper (at 20 cm from the cutting height or at the tallest point if stem height < 20 cm). Since Elephant grass stems are oval-shaped, stem diameter was measured at its widest point.

Next, the 10 plants were weighed, separated into leaves (fresh, senescent, or dry leaf blades) and stems (fresh or dry stems and leaf sheaths), and dried in a forced air circulation oven, at 65 °C for 72 h (MELO et al., 2002; RODRIGUES, 2010), to determine forage mass of each plant part.

Tiller density (tillers.m^{-2}) was estimated by counting all tillers in the three central rows of each plot at 30, 60 and 150 days after planting (DAP). All basal and aerial (axillary) tillers were counted over two linear meters in the central row before the cuts, to estimate basal, aerial and total tiller densities. Additionally, genotypes were considered to have flowered if 5% or more of all plants in at least two of the three replicates had inflorescences.

Analysis of variance (ANOVA) was calculated for each forage mass variable and agronomic trait using the mixed models procedure in SAS software (SAS INSTITUTE, Cary, NC, USA). Treatment means were compared by the Student's t (P<0.05) using the PDIFF option of the LSMEANS statement. Correlation coefficients were calculated according to the formula:

$$r = \frac{n\Sigma xy - \Sigma x \Sigma y}{\sqrt{n\Sigma x^2 - (\Sigma x)^2}\,\sqrt{n\Sigma y^2 - (\Sigma y)^2}}$$

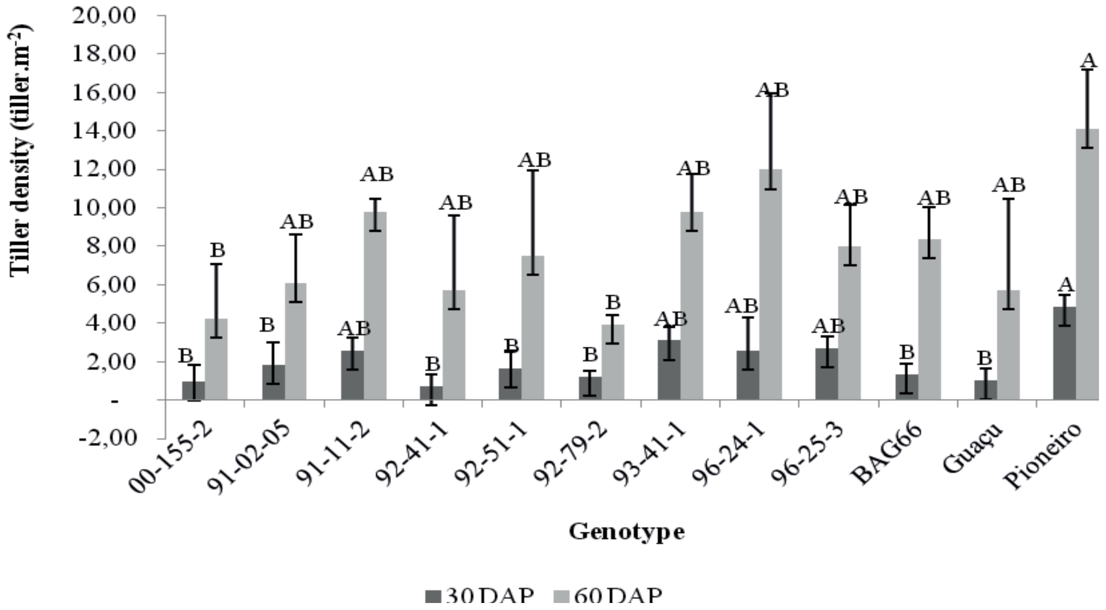
where, r = correlation coefficient, x = forage mass variable, and y= agronomic variable.

Results and Discussion

Trial 1: Free-growth system

During establishment, significant differences in total tiller density across genotypes were observed at 30 (P=0.0004) and 60 (P=0.0144) days after planting (DAP, Figure 2). Establishment was slow, consistent with seedling planting and the forage species used. At 30 days after planting, total tiller density was low, ranging from 0.71 tiller.m^{-2} in genotype CNPGL 92-41-1 to 4.84 tillers.m^{-2} in genotype Pioneiro (Figure 2). At 60 DAP, total tiller density was still low, ranging from 4.3 tillers.m^{-2} in genotype CNPGL 00-155-2 to 14.1 tillers.m^{-2} in genotype Pioneiro (Figure 2).

Figure 2. Total tiller density (tillers.m-2) at 30 and 60 days after planting (DAP) in Elephant grass genotypes. Means followed by different letters are significantly different (P<0.05).



Total (P<0.001) and aerial (P<0.001) tiller density was significantly different across Elephant grass genotypes at 150 DAP, but there was no significant difference in basal tiller density (P=0.1985) across genotypes (Table 1), despite the positive correlation between forage mass and this structural trait (r=0.4096, Table 2). Aerial tiller density was highest in genotypes Pioneiro and CNPGL 00-155-2 (192.7 and 190.1 tillers.m^{-2}, respectively), despite the long growth period and the maintenance of the shoot apical meristem.

Table 1. Basal, aerial, and total tiller density (tillers.m^{-2}) at 150 DAP, and tiller flowering in Elephant grass genotypes in the free-growth system (Trial 1).

Genotype	Tillers.m^{-2}			Flowering
	basal	aerial	total	
CNPGL 00-155-2	16.57(5.27)	190.11^{ab}(58.03)	205.89^{a}(63.28)	No
CNPGL 91-02-5	11.47(4.01)	0.00^{c}(0.00)	13.44^{b}(4.01)	No
CNPGL 91-11-2	12.97(2.45)	42.11^{c}(17.86)	58.89^{b}(20.24)	Yes
CNPGL 92-41-1	10.49(1.57)	32.44^{c}(5.58)	43.33^{b}(7.05)	Yes
CNPGL 92-51-1	15.33(4.09)	10.44^{c}(4.43)	22.11^{b}(3.37)	No
CNPGL 92-79-2	9.37(0.66)	0.22^{c}(0.38)	7.88^{b}(0.76)	No
CNPGL 93-41-1	9.60(4.66)	1.33^{c}(2.30)	11.44^{b}(6.92)	Yes
CNPGL 96-24-1	10.66(2.82)	11.50^{c}(0.70)	25.22^{b}(2.12)	No
CNPGL 96-25-3	12.18(5.16)	54.44^{c}(52.04)	68.55^{b}(49.33)	Yes
Mineiro IPEACO	12.57(5.33)	77.77^{bc}(53.24)	90.55^{ab}(58.04)	Yes
Guaçu	16.47(6.13)	0.33^{c}(1.01)	11.39^{b}(6.60)	No
Pioneiro	19.33(9.87)	192.66^{a}(86.78)	212.00^{a}(93.14)	Yes

Means (standard error) followed by different letters in a column are significantly different (P<0.05).

Table 2. Correlation coefficients (r) between forage mass and agronomic traits in different Elephant grass genotypes at 150 DAP and after cutting and regrowth.

Agronomic trait	Correlation coefficient (r)	
	Free growth	After regrowth
basal tillers (tillers.m^{-2})	+0.4096	-0.0807
aerial tillers (tillers.m^{-2})	+0.1893	-0.2006
total tillers (tillers.m^{-2})	+0.2107	-0.1964
leaves (%)	+0.1455	-0.0273
stems (%)	-0.2791	-0.0215
leaf/stem ratio	+0.1801	-0.0274
plant height (m)	+0.1190	-0.1937
stem diameter (mm)	-0.4879	-0.0026
internodes (number.stem^{-1})	0.0008	+0.0165

Forage mass (P=0.01163) and leaf/stem ratio (P=0.0393) were significantly different across grass genotypes in the free-growth system (Table 3). Mean forage mass was 13.8 kg.ha^{-1} DM, considerably lower than the 43.5 kg.ha^{-1} DM reported by Saraiva and Konig (2013) for Elephant grass fertilized with sewage treatment plant (STP) sludge at a cutting frequency of 160 days, which indicates the need for increased fertilization for the species (RAIJ et al., 1996). Moreover, tiller density is an important canopy structure parameter affecting forage production (LEMAIRE; CHAPMAN, 1996), but the tillering potential of each genotype can only be achieved if the apical meristem is removed by grazing or pruning (LANGER, 1963). Thus, forage mass may have been adversely affected by using the free-growth system, leading to a drastically decreased tiller production after 90 days, similar to what was found by Rodrigues et al. (2012) for Jaraguá grass (*Hyparrheni rufa*), Mombaça grass (*Panicum maximum* cv. Mombaça), and Xaraés grass (*Brachiaria brizantha* cv. Xaraés). We also found in this trial, a positive relationship between forage mass and basal tiller density (r=0.4096) and weak relationships between forage mass and aerial (r=0.1893) and total (r=0.2127) tiller density (Table 2).

Table 3. Forage mass (kg.ha^{-1} DM), number of internodes (I), diameter (D), canopy height (H), and leaf/stem ratio (L/S) at 150 DAP in Elephant grass genotypes in the free-growth system (Trial 1).

Genotype	kg.ha^{-1} DM	I (n)	D (mm)	H (cm)	L/S
CNPGL 00-155-2	16.667^{ab}(1476)	16.80^{bcd}(1.35)	13.76^{bcd}(0.45)	3.04^{abc}(0.38)	0.41^{AB}(0.07)
CNPGL 91-02-5	14.612^{b}(1476)	15.62^{cd}(3.67)	13.44^{bcd}(0.77)	2.51^{abc}(0.12)	0.37^{ABC}(0.09)
CNPGL 91-11-2	12.559^{b}(1476)	17.27^{abcd}(0.49)	13.39^{bcd}(0.98)	2.92^{abc}(0.18)	0.31^{ABC}(0.07)
CNPGL 92-41-1	17.395^{a}(1.837)	18.40^{abc}(1.22)	16.10^{ab}(1.53)	3.06^{ab}(0.33)	0.36^{ABC}(0.07)
CNPGL 92-51-1	16.328^{ab}(1476)	18.43^{ab}(1.45)	13.43^{bcd}(1.36)	2.34^{abc}(0.10)	0.51^{A}(0.07)
CNPGL 92-79-2	7.494^{c}(1476)	15.63^{cd}(0.55)	18.13^{a}(1.25)	2.14^{bc}(0.46)	0.27^{BC}(0.09)
CNPGL 93-41-1	13.188^{b}(1476)	17.23^{bcd}(3.06)	14.26^{abc}(0.64)	0.59^{abc}(0.51)	0.24^{BC}(0.07)
CNPGL 96-24-1	15.682^{ab}(1.839)	16.13^{cd}(1.34)	14.44^{abc}(0.28)	0.40^{abc}(0.15)	0.23^{BC}(0.09)
CNPGL 96-25-3	13.082^{b}(1476)	22.68^{a}(0.28)	14.49^{abc}(0.21)	2.93^{abc}(0.15)	0.25^{BC}(0.07)
Mineiro IPEACO	12.987^{b}(1476)	17.10^{bcd}(1.03)	11.50^{cd}(2.16)	3.28^{a}(0.19)	0.17^{C}(0.07)
Guaçu	15.279^{ab}(1476)	12.53^{d}(1.48)	13.64^{bcd}(0.56)	2.02^{c}(0.69)	0.54^{A}(0.09)
Pioneiro	15.267^{b}(1476)	17.33^{abcd}(0.91)	9.69^{d}(1.34)	2.96^{abc}(0.29)	0.16^{C}(0.07)

Means (standard error) followed by different letters in a column are significantly different (P<0.05).

Forage species that have a high proportion of leaves to stems usually have high protein content, digestibility, and consumption rates (WILSON; MINSON, 1980). A low proportion of leaves in the forage is also associated with low cutting frequencies, because longer regrowth periods result in increased competition for light and greater stem production in tropical species (SILVA; CORSI, 2003). The low leaf/stem ratio measured in this trial is consistent with the long growing period (150 days), and similar findings were reported for other forage species grown in the free-growth system (RODRIGUES et al., 2012). Genotype CNPGL 92-51-1 and cv. Guaçu had significantly higher leaf/stem ratios (0.51 and 0.54, respectively) than the other genotypes (less than 0.50), indicating that their nutritional value could be higher than that of the other genotypes investigated.

There were significant differences in number of internodes (P=0.0021), stem diameter (P=0.003), and canopy height (P=0.005) across grass genotypes (Table 3). Each node has an axillary bud, suggesting that tiller production may be higher in genotypes with higher internode counts. The mean number of internodes ranged from 12.5 in cv. Guaçu to 22.8 in genotype CNPGL 96-25-3. Stem diameter ranged from 9.7 mm in cv. Pioneiro to 18.1 mm in genotype CNPGL 92-79-2, indicating that stem diameter in the former was small, despite the high proportion of stems in the forage mass of this cultivar. Stem diameter was inversely associated with forage mass (r=-0.4879, Table 2).

Plant (stem) height in the free-growth system ranged from 0.40 m (in genotype CNPGL 96-24-1) to 3.28 m (in cv. Mineiro IPEACO) at 150 DAP (Table 3), and all genotypes were above the cutting height of 1.8 m for tall cultivars in the rainy season (CÓSER, 1995) and 1.0 m for grazing of Cameron grass (VOLTOLINI et al., 2010). Andrade and Gomide, (1972, adapted by CARVALHO, 1981), studying cv. A-146 Taiwan, reported that plant height increased until 196 DAP (3.16 m), while forage mass stopped growing after 140 DAP , indicating that plant height may not be positively associated with forage mass during the growing period. Accordingly, in the current study, the correlation coefficient between forage mass and plant height was low (r=0.119), indicating a weak relationship between the two variables (Table 2).

Flowering time varied across genotypes, and genotypes CNPGL 91-11-2, CNPGL 92-41-1, CNPGL 93-41-1, CNPGL 96-25-3, Pioneiro, and Mineiro IPEACO had flowered by the autumn of 2007 (end of May, data not shown), while the remaining genotypes did not during the period of the experiment. Knowledge about the flowering time of different genotypes in a region is important because of the physiological and morphological changes that occur in the reproductive phase. According to Pereira (1994), there is a sharp reduction in vegetative growth of Elephant grass during the reproductive phase, which varies across genotypes, to meet the energy requirements of reproduction. The reproductive phase is also characterized by translocation of soluble carbohydrates from stems and leaves to the inflorescences, increased lignification of cells, and lower leaf/stem ratio, decreasing forage quality.

Trial 2: cutting and regrowth

Basal (P=0.0116), aerial (P=0.002), and total (P<0.001) tiller density were significantly different across Elephant grass genotypes after regrowth. Basal tiller density was highest in cv. Pioneiro (44.77 tillers.m^{-2}) and was lowest in genotypes CNPGL 92-79-2 (23.44 tillers.m^{-2}) and CNPGL96-24-1 (24.0 tillers.m^{-2}). As in the free-growth trial, genotypes Pioneiro and CNPGL 00-155-2 had the highest total (126.6 and 111.9 tillers.m^{-2}, respectively) and aerial (81.78 and 70.44 tillers.m^{-2}, respectively) tiller densities (Table 4). Santos et al. (2003) reported much higher aerial and basal tiller densities, of 331.15 and 17.8 tillers.m^{-2}, respectively, in cv. Pioneiro managed at a cutting frequency of 35 days; the difference is likely due to the higher fertilization and cutting frequency used in their study. It should be noted that cv. Pioneiro was the first cultivar released in Brazil specifically for use in rotational grazing systems and has high aerial and basal tiller densities, which was also observed in the current study, even when managed at cutting frequencies of 60 to 90 days. Carvalho et al. (2006) evaluated the tillering patterns of Elephant grass cv. Napier over six grazing cycles and reported that aerial tillers had lower mass (0.7–1.7 $g.tiller^{-1}$), higher density (142–344 $tillers.m^{-2}$), and lower forage accumulation rates (47.8–71.8 $kg.ha^{-1}$ DM per day) than basal tillers. The authors concluded that, to achieve higher yields, management practices should promote basal tiller development in spring (as a basis for production of aerial tillers) and aerial tiller development in summer. Mello et al. (2002) also reported a positive relationship between basal tiller density and forage mass in the dry season, which they attributed to the higher weight of basal tillers compared to aerial tillers.

Table 4. Basal, aerial, and total tiller density ($tillers.m^{-2}$) and tiller flowering in Elephant grass genotypes at 90 days after cutting and regrowth (Trial 2).

Genotype	Tiller density ($tillers.m^{-2}$)			Flowering
	basal	aerial	total	
CNPGL 00-155-2	41.44^{ab}(9.39)	70.44^{ab}(63.28)	111.89^{a}(55.50)	Yes
CNPGL 91-02-5	28.67^{ab}(3.60)	10.57^{bc}(17.52)	39.44^{b}(21.04)	No
CNPGL 91-11-2	32.44^{ab}(4.07)	20.22^{bc}(8.59)	52.66^{b}(7.26)	Yes
CNPGL 92-41-1	26.22^{ab}(9.98)	0.00^{c}(0.00)	26.22^{b}(9.98)	No
CNPGL 92-51-1	38.44^{ab}(6.92)	0.00^{c}(0.00)	38.44^{b}(6.92)	No
CNPGL 92-79-2	23.44^{b}(5.10)	0.0^{c}(0.00)	23.44^{b}(5.10)	No
CNPGL 93-41-1	27.11^{ab}(7.18)	0.77^{c}(1.34)	27.88^{b}(6.79)	Yes
CNPGL 96-24-1	24.00^{b}(1.19)	3.89^{c}(5.35)	27.89^{b}(5.01)	No
CNPGL 96-25-3	26.66^{ab}(10.73)	27.22^{abc}(11.47)	53.89^{b}(14.68)	Yes
Mineiro IPEACO	30.44^{ab}(1.57)	22.55^{abc}(5.73)	53.00^{b}(6.64)	Yes
Guaçu	31.44^{ab}(8.76)	0.00^{c}(0.00)	31.44^{b}(8.76)	No
Pioneiro	44.77^{a}(2.98)	81.78^{a}(10.64)	126.55^{a}(9.18)	Yes

Means (standard error) followed by different letters in a column are significantly different (P<0.05).

Forage mass (P=0.0002) were significantly different across Elephant grass genotypes after regrowth (Table 5). Forage dry matter was low compared to the usual potential for this species, being highest in genotype CNPGL 93-41-1 (5,909 $kg.ha^{-1}$ DM), followed by genotype CNPGL 92-41-1, cvs. Mineiro IPEACO and Guaçu, genotype CNPGL 91-11-2 and cv. Pioneiro, with no significant difference in across these six genotypes (Table 5). The lowest forage mass was found for the hexaploid hybrid CNPGL 00-155-2 (2,235 $kg.ha^{-1}$ DM), although with no significant difference to genotypes CNPGL 96-25-3, CNPGL 96-24-1, and CNPGL 92-51-1, suggesting that persistence for these genotypes is low under the experimental conditions. However, long-term studies with higher nutrient availability are required to determine the persistence of different grass genotypes. Genotype CNPGL 92-79-2 had moderate forage mass that was also not significantly different from that of low- mass genotypes. This contrasts with the results of Lima et al. (2007) with this genotype: they reported high forage mass (13.5 $kg.ha^{-1}$ DM) and digestible dry matter yield (8.06 $kg.ha^{-1}$ DDM) 56 DAC (days after the standardization cut), similar to the values that they observed for cvs. Cameroon and Mineiro IPEACO.

Leaf/stem (P<0.0001) ratio was significantly different across genotypes and ranged from 0.54 in cv. Pioneiro to 1.33 in cv. Guaçu. These are low values compared to those reported by Lima et al. (2007), which ranged from 0.95 in Napier grass to 1.43 in genotype CNPGL 91-25-1 in an experiment with a shorter regrowth period (56 DAC).

Table 5. Forage mass (kg.ha^{-1} DM), number of internodes (I), diameter (D), canopy height (H), and leaf/stem ratio (S/L) in Elephant grass genotypes after cutting and regrowth (Trial 2).

Genotype	kg.ha^{-1} DM	I (n)	D (mm)	H (cm)	L/S
CNPGL 00-155-2	2.234^{c}(744)	6.76^{ab} (0.70)	8.05^{cd}(0.73)	1.43^{ab}(0.09)	0.51^{d}(0.66)
CNPGL 91-02-5	2.658^{bc}(579)	2.80^{ab}(1.07)	9.81^{abcd}(1.78)	0.60^{b}(0.15)	1.01^{abc}(0.31)
CNPGL 91-11-2	3.623^{abc}(850)	6.33^{ab} (1.05)	11.53^{abc}(0.44)	1.21^{ab}(0.39)	0.74^{bcd}(0.22)
CNPGL 92-41-1	5.036^{ab}(250)	6.16^{ab}(3.55)	11.09^{acd}(0.78)	0.75^{b}(0.29)	0.90^{abc}(0.36)
CNPGL 92-51-1	2.565^{c}(541)	5.16^{ab}(0.92)	10.79^{abcd}(2.03)	1.12^{ab}(0.30)	0.47^{cd}(0.08)
CNPGL 92-79-2	2.738^{bc}(441)	2.93^{ab}(1.55)	13.18^{a}(3.70)	0.61^{b}(0.63)	0.82^{abcd}(0.26)
CNPGL 93-41-1	5.909^{a}(1.735)	4.33^{ab}(3.30)	9.73^{abcd}(2.21)	0.98^{ab}(0.51)	0.70^{bcd}(0.27)
CNPGL 96-24-1	2.541^{c}(821)	2.10^{b}(0.62)	11.85^{ab}(1.52)	0.45^{b}(0.05)	1.08^{ab}(0.03)
CNPGL 96-25-3	2.471^{c}(774)	5.66^{ab}(1.36)	9.29^{bcd}(1.85)	0.99^{ab}(0.23)	0.53^{cd}(0.22)
Mineiro IPEACO	4.364^{abc}(1.650)	6.00^{ab}(0.85)	9.26^{bcd}(0.56)	2.00^{a}(1.0)	0.57^{cd}(0.27)
Guaçu	4.143^{abc}(1.254)	2.10^{b}(0.85)	13.15^{a}(2.04)	0.56^{b}(0.11)	1.33^{a}(0.11)
Pioneiro	3.504^{abc}(820)	7.40^{a}(1.37)	7.62^{d}(1.58)	1.59^{ab}(0.49)	0.54^{d}(0.01)

Means (standard error) followed by different letters in a column are significantly different (P<0.05).

There were significant differences in number of internodes (P=0.0069), stem diameter (P<0.0001), and canopy height (P=0.005) across Elephant grass genotypes (Table 5). The mean number of internodes per stem ranged from 2.1 in cv. Guaçu to 7.4 in cv. Pioneiro (Table 5), indicating that the latter genotype had the highest number of axillary buds per tiller and best aerial tillering potential. Conversely, stem diameter was smallest in cv. Pioneiro (7.62 mm) and largest in cv. Guaçu (13.15 mm) (Table 5). These results show that, even though the two cultivars had similar forage mass, they had different plant structures, potentially resulting in different nutritional values. Stem diameter values are within the range described by Mello et al. (2002), who reported diameter values ranging from 4.5 mm for cv. Guaçu in the dry season to 20.6 mm for Elephant grass cv. Pinda in the rainy season. Also, in that study, the authors reported positive relationships between stem diameter and total and leaf dry matter.

Plant (stem) height was greatest in genotypes CNPGL 00-155-2, CNPGL 91-11-2, CNPGL 92-51-1, CNPGL 96-25-3, CNPGL 93-41-1, and in cvs. Mineiro IPEACO and Pioneiro (Table 5). The plant height achieved by a genotype may be related to its productive potential under cutting conditions. Indeed, Lima et al. (2007) evaluated Elephant grass genotypes subjected to cutting and reported that plant height was highest in the most productive genotypes (Cameroon, Mineiro IPEACO, and CNPGL 92-79-2). Mello et al. (2002) also found a positive relationship between plant height and total and leaf dry matter in the dry and rainy seasons for 71 Elephant grass clones (pooled data). In contrast, this study found no positive relationship between plant height and was highest in cv. Guaçu despite its short height, whereas forage mass was low in genotypes CNPGL 00-155-2, CNPGL 92-51-1, and CNPGL 96-25-3 even though they were among the tallest genotypes.

Canopy structure was different between cvs. Guaçu and Pioneiro: cv. Guaçu was short (0.56 m), had few internodes and thicker stems without aerial tillers or inflorescences, whereas cv. Pioneiro was tall (1.59 m), had many internodes and thin stems with high aerial tiller and inflorescence numbers. This resulted in low leaf/stem ratio for cv. Pioneiro (0.54) and a high proportion of leaves to stems in cv. Guaçu (1.33). Taken in isolation, these results suggest that the nutritional value of forage is lower in cv. Pioneiro than in cv. Guaçu, but the small stem diameter of cv. Pioneiro plants may compensate for their high proportion of stem in the forage mass.

After regrowth, all correlations between forage mass and agronomic traits were weak (Table 2), which may be due to phenotypic plasticity, i.e., the tendency of the plants to maintain constant the forage accumulation through the modulation in the amount and shape of structural components (leaf size, tiller density and leaves per tiller). The evaluation of different species or cultivars under similar grazing conditions may occasionally favor or disfavor certain genotypes depending on their adaptation to the management system, both in grazing and in cutting experiments in which assessments are conducted without prior knowledge of the ecophysiology of the plants (RODRIGUES, 2004). Nevertheless, these standard practices are useful in the early evaluation of new genotypes, enabling their characterization under specific management conditions (RODRIGUES et al., 2012). Thus, future studies must consider the ecophysiological characteristics of each genotype to achieve their full yield potential.

Conclusions

Forage mass in the free-growth system and after a 90-day regrowth period was low, indicating the need for higher nutrient inputs for the species. After regrowth, stem mass was higher than leaf mass in the most genotypes, except in cv. Guaçu, CNPGL 91-02-5 e CNPGL 96-24-1. Genotype CNPGL 00-155-2 and cv. Pioneiro had the highest aerial tiller density.

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