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Morphogenic, structural, and chemical characteristics of Brachiaria grass (*Urochloa decumbens* Stapf.) pastures in monoculture and intercropped with forage peanut under two grazing intensities

Características morfogênicas, estruturais e químicas de capim-braquiária em monocultura e consorciado com amendoim forrageiro sob duas intensidades de pastejo

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Highlights

Forage peanut improves the morphogenic and structural traits of Brachiaria grass.
The 5 cm post-grazing height improves the chemical composition of Brachiaria grass.
Forage peanut established at 40–60 cm row spacing do not affect Brachiaria grass.

Abstract

The objective of this study was to evaluate the morphogenic, structural, and chemical characteristics of Brachiaria grass (*Urochloa decumbens*) intercropped with forage peanut (*Arachis pintoi*) under three-row spacings (40, 50, and 60 cm) and two post-grazing residual heights (5 and 15 cm). The experiment was performed in a randomized block design with a factorial scheme (3 x 2) with four replicates. The structural and morphogenic characteristics were considered in a factorial scheme (3 × 2) + 1 (an additional treatment of Brachiaria grass in monoculture). Chemical characteristics sampled by cutting and by hand plucking were evaluated. Brachiaria grass had the highest crude protein (CP) content at 5 cm, whereas forage peanut had the highest CP content at 15 cm in the first year, however, there was no difference in the second year. Compared to monoculture, intercropping resulted in lower final stem size, a greater number of live leaves, and increases in the following metrics: leaf elongation rate, final leaf size, and leaf life duration, most

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consistently with 5 cm residual height in the second year. The forage peanut improved the morphogenic and structural characteristics of Brachiaria grass primarily when managed at 5 cm post-grazing height, regardless of row spacing.
Key words: Crude protein. Hand plucking. Leaf duration. Leaf elongation rate. Row spacings.

Resumo

Objetivou-se avaliar as características morfogênicas, estruturais e químicas do capim-braquiária (*Urochloa decumbens*) consorciado com amendoim forrageiro (*Arachis pintoi*) em três espaçamentos (40, 50 e 60 cm) e em duas alturas residuais pós-pastejo (5 e 15 cm). O experimento foi conduzido em delineamento em blocos casualizados, em esquema fatorial (3 x 2), com quatro repetições. As características estruturais e morfogênicas foram consideradas em esquema fatorial (3 × 2) + 1 (um tratamento adicional de capim-braquiária em monocultivo). Foram avaliadas as características químicas amostradas por corte e via pastejo simulado. O capim-braquiária apresentou o maior teor de proteína bruta (PB) a 5 cm, enquanto o amendoim forrageiro apresentou o maior teor de PB a 15 cm, no primeiro ano, no entanto, não houve diferença no segundo ano. Comparado à monocultura, o consórcio resultou em menor tamanho final do colmo, maior número de folhas vivas e aumento nas seguintes métricas: taxa de alongamento da folha, tamanho final da folha e duração da vida da folha, mais consistentemente com altura residual de 5 cm, no segundo ano. O amendoim forrageiro melhorou as características morfogênicas e estruturais do capim-braquiária, principalmente quando manejado a 5 cm de altura pós-pastejo, independentemente do espaçamento entre linhas.
Palavras-chave: Duração da folha. Espaçamentos de plantio. Pastejo simulado. Proteína bruta. Taxa de alongamento da folha.

Introduction

Species of *Brachiaria* (syn. *Urochloa*) are the main grasses used for grazing ruminants in tropical regions (Jank et al., 2014). However, large areas of pasture have low productivity because of nitrogen deficiencies in the soil-plant-animal system (Cardoso et al., 2020).

The use of forage legumes may contribute to increased sustainability in tropical and subtropical pastures (Boddey et al., 2020) because of biological nitrogen fixation and improvements in the diet quality of grazing ruminants (Lüscher et al., 2014). Thus, the introduction of legumes, especially those intercropped with grass, is a viable option for increasing forage productivity and quality (Cardoso et al., 2016; Lüscher et al., 2014; Homem et al., 2021).

The limited use of forage legumes, particularly in tropical pastures, is partly due to limited knowledge about their use during grazing. This makes it difficult to establish proper management goals. Among legumes, forage peanut stand out as warm-season legumes with the potential for intercropping with grasses, mainly because of their clonal expansion (Tamele et al., 2018). This provides a competitive advantage for legumes and increases their chances of persistence in the plant community (Simeão et al., 2017).

Management conditions substantially influence the development and final structure of forage canopies. For example, grazing intensity and frequency directly affect the development of plant components and, consequently, pasture structure (S. C. da Silva et al., 2019).

Defoliation intensity is one of the main factors that affects light competition. Increasing defoliation intensity allows more solar radiation to reach the canopy base, which may favor the growth of prostrate plants such as forage peanut. Additionally, the density or row spacing of legumes may be related to the chemical and structural characteristics of the intercropped pastures (Tamele et al., 2018).

The effects of grazing intensity on the structural and morphogenic characteristics of forage grasses have been well described in previous studies. However, there are few reports on intercropping and how legume row spacing affects these variables. The hypothesis of this study is that, for Brachiaria grass (*Urochloa decumbens* (Stapf) R.D. Webster) that is intercropped with forage peanut cv. Belmonte (*Arachis pintoi* Krapov. & W.C. Greg.), different row spacings and grazing intensities will affect the morphogenic, structural, and chemical characteristics of grass. This study aimed to evaluate the structural and morphogenic characteristics and chemical composition of Brachiaria grass intercropped with forage peanut under three-row spacings (40, 50, and 60 cm) and two post-grazing residual heights (5 and 15 cm).

Materials and Methods

Experimental site and design

This study was conducted at the Federal University of Viçosa, Viçosa, Minas Gerais, Brazil (20° 45’ S, 42° 51’ W; elevation of 651 m a.s.l.) during the rainy and dry seasons over two years (January 2015 to October 2015 and February 2016 to December 2016). Accumulated precipitation and average temperature data during the experimental period were obtained from the Viçosa Meteorological Station (Figure 1).

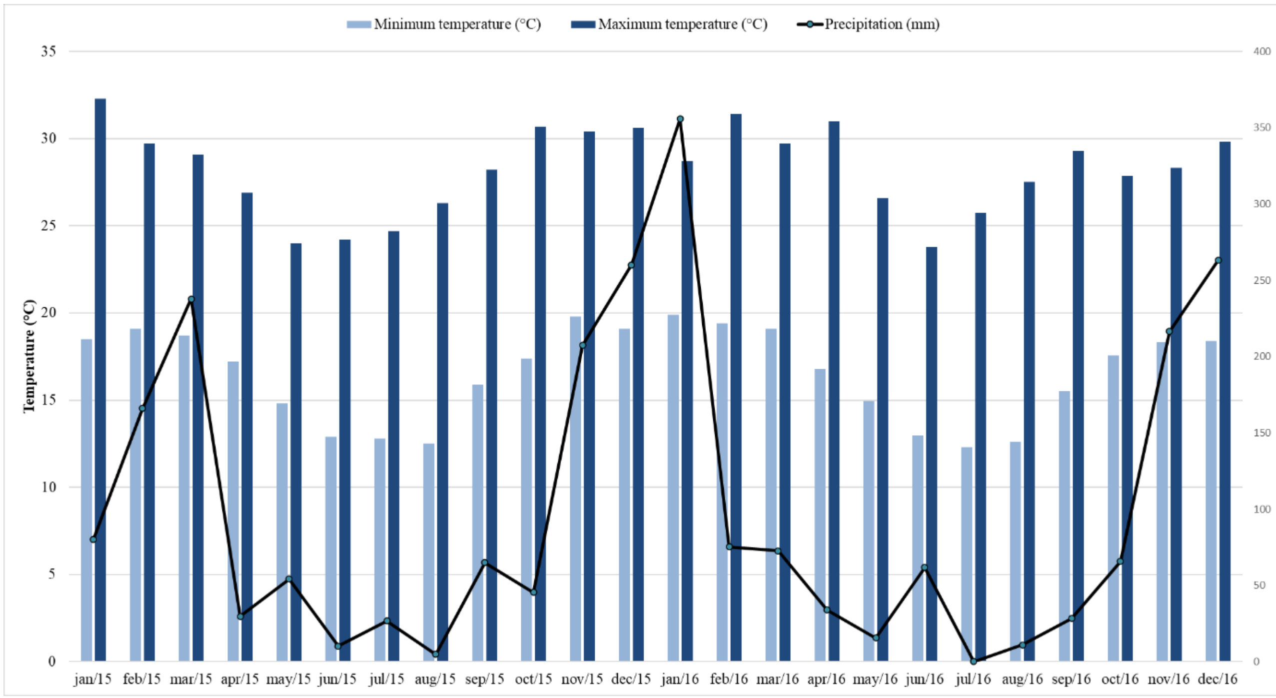

Figure 1. Weather data from January 2015 to December 2016, in Viçosa, Minas Gerais, Brazil.
Source: Instituto Nacional de Meteorologia do Brasil [INMET] (2019).

The soil was classified as a red-yellow dystrophic latosol (H. G. Santos et al., 2018). Soil samples were collected with a probe from 0–10 cm and 0–20 cm layers in August 2013, and their chemical composition was analyzed (Table 1).

Table 1
Chemical analysis of soil samples collected in the 0–10 cm and 0-20 cm layers in the experimental area

Layers	pH	P	K	Ca^{+2}	Mg^{+2}	Al^{3+}	EB	(t)	(T)	V	m	P-rem
(cm)	H_2O	mg dm^{-3}		cmol$_c$ dm^{-3}						%		mgL^{-1}
0 - 10	5.5	1.4	54	1.6	0.9	0.0	2.64	2.64	710	37	0	9.6
10 - 20	5.1	1.0	24	0.9	0.3	0.4	1.26	1.66	5.06	25	24	14.0

pH - in water; KCl and $CaCl_2$ - 1:2.5 ratio; P-K - Mehlich^{-1} Extractor; Ca-Mg - Extractor KCl^{-1} mol/L; EB - sum of exchangeable bases; t - capacity of effective cation exchange; T - cation exchange capacity at pH 7.0; V - base saturation index; m - aluminum saturation; P-rem - Remaining phosphorus.

The experimental area was mowed, plowed, and harrowed during tillage. The correction and fertilizer application of the soil for a medium-level technological system were conducted according to Comissão de Fertilidade do Solo do Estado de Minas Gerais [CFSEMG] (1999). A dose of 2.2 t ha^{-1} of dolomitic limestone was incorporated into the soil three months before planting. In December 2013, furrows with 40, 50, and 60 cm of row spacing were opened for the planting of stolons of forage peanut at 10-cm depth, where half-doses of 90 kg ha^{-1} of P_2O_5, 50 kg ha^{-1} of K_2O, and 50 kg ha^{-1} of fritted trace elements (2.5% B, 0.1% Co, 1.0% Cu, 4.0% Fe, 4.0% Mn, 0.1% Mo, 7.0% Zn) were applied. At the end of February 2014, 3 kg ha^{-1} of Brachiaria grass seeds were sown at row spacing by broadcasting, along with the application of the other half of the fertilizer doses. In January 2015, 50 kg ha^{-1} of P_2O_5 and 40 kg ha^{-1} of K_2O were applied to the experimental units according to soil analysis.

The experiment was performed in a randomized block design (RBD) with a factorial scheme (3 x 2) with four replicates. Three-row spacings of forage peanut (40, 50, and 60 cm) and two defoliation intensities (post-grazing heights of 5 and 15 cm) were evaluated, totaling 24 paddocks. For the structural and morphogenic characteristics, we considered the RBD with a factorial scheme (3 × 2) + 1 (an additional treatment of Brachiaria grass in monoculture) with four replicates. The Brachiaria grass monoculture did not receive fertilizer application or grazing management to represent an extensive management area.

Pasture canopy height was monitored weekly during the summer and once every 15 d during the winter. Using a graduated ruler, 24 measurements were taken per paddock, each with an area of 150 m^2 (10 × 15 m), and the average canopy height was used for grazing management. Grazing was performed by non-lactating Holstein × Zebu crossbred cows (430–450 kg) in the first year and by Nelore cows (450 kg) in the second year, using the mob-stocking technique when the average forage height in the paddocks reached 25 cm. The animals were removed from the paddocks when residual heights of 5 and 15 cm were reached. This work was conducted with the approval of the Ethics Commission on the Use of the Farm Animals of Universidade Federal de Viçosa (CEUAP-UFV) (Number protocol: 31/2016).

Chemical analysis

In year 1 (March to April 2015) and year 2 (March to April 2016), two samples were collected within a circle with a diameter of 0.25 m², and the plants were cut 5 cm from the ground using a cleaver before grazing in each paddock. These two samples were taken at representative points of average pasture canopy height. All the samples were separated into forage grasses and legumes.

Chemical composition analysis was performed on samples collected by manual removal – hand plucking (Muir et al., 2008) in the second year (March to April 2016). In addition to the grazing behavior of the animals, the area, height, and parts of the plant consumed were considered. Samples were collected manually by the same observer to obtain a portion of the forage similar to that selected by grazing animals in the three stages. The first stage was 20 min after the animals were allocated to the respective paddocks to be grazed. The second and third stages were 2 h after the first stage and the second stage (or near the removal of the animals), respectively, to minimize animal selectivity and increase the representativeness of consumption. These samples were used to prepare composite samples using a paddock.

To determine crude protein (CP) and dry matter (DM) content, samples were dried in a forced-air oven at 55 °C until reaching a constant mass, then ground in a Wiley mill (model TE-650, Tecnal Equipamentos Cientificos, Piracicaba, Sao Paulo, Brazil) with a 1-mm sieve. Methods 976.05 and 930.15 were used for CP and DM, respectively (Association of Officiating Analytical Chemists [AOAC], 2005). In addition, neutral detergent fiber was corrected for ash and protein (NDFap) content (Detmann et al., 2012).

Morphogenetic and structural characteristics

The morphogenesis study was conducted according to the marked tillering technique (Carrere et al., 1997), and data were collected over two years: year 1 (January 31, 2015, to April 4, 2015) and year 2 (February 15, 2016, to April 27, 2016).

Two points were selected per paddock, and three tillers at each point were marked with colored wires at their base. The tillers were spaced 1 meter apart, and this marking was done at the beginning of each regrowth period, following the removal of animals. In the evaluation of each selected tiller, the leaves were enumerated and classified as emergent (without visible ligula), fully expanded (with visible ligula), or senescent (when part of the leaf blade started the senescence process).

Leaf blade length was measured using a graduated ruler according to the leaf growth stage. For fully expanded leaves, length was measured from the tip of the leaf blade to the ligula. The last expanded leaf ligula was used as the measurement reference for emerging leaves. For senescent leaves, we considered the length from the leaf blade tip to the point at which the senescence became apparent. Stem length (stem + sheath) was measured as the distance from ground level to the last fully expanded leaf.

The following variables were obtained from the readings: final leaf size (FLS; cm), final stem size (FSS; cm), leaf life (LL; days, d), number of live leaves (NLL; leaf tillers^{-1}), and number of dead leaves (NDL; leaf tillers^{-1}). In addition, from these evaluations, the following morphogenesis variables were calculated: leaf appearance rate (LAR; leaf tillers^{-1} d^{-1}), the average number of leaves per tiller by the number of days of the evaluation interval; leaf elongation rate (LER; cm tillers^{-1} d^{-1}), the increase in length of the emerging leaf blade per tiller by the number of days of the evaluation interval; stem elongation rate (SER; cm tillers^{-1} d^{-1}), the increase in stem length per tiller by the number of days of the evaluation period; and leaf senescence rate (LSR; cm tillers^{-1} d^{-1}), the increase in length of the senescent leaf blade per tiller by the number of days of the evaluation interval.

Tillering dynamic

Tillering dynamics in Brachiaria grass were evaluated from June 13, 2015, to September 10, 2015 (the dry season), and from October 10, 2015, to December 17, 2015 (the rainy season), according to rainfall. All tillers within the two plastic circles of 30 cm diameter per paddock were evaluated every 28 d, according to Sbrissia et al. (2010). In each evaluation, the tillers were marked with wires of different colors, and dead tillers from the previous reading were registered and removed.

The tillers were counted and classified as alive or dead, and the collected data were used for the following calculations. The total number of live tillers was: new tillers + total live tillers from the previous reading – dead tillers from the current reading. The tiller appearance rate (TAR) was calculated as the number of new tillers/total number of live tillers in the previous reading (tillers/100 tillers day). Tiller mortality rate (TMR) was defined as dead tillers/total live tillers in the previous reading (tillers/100 tillers per day). The stability index (P1/P0) of the tiller population was calculated according to the methodology described by Bahmani et al. (2003) using the following expression:

$$P1/P0 = TSR\ (1 + TAR)$$

where: TSR (tiller survival rate) = 1 - TMR.

Statistical analyses

Data were subjected to an analysis of variance using a factorial scheme (3 x 2) in a randomized complete block design. The data for two years (chemical composition analysis) and two seasons of the year (tillering dynamic analysis) were used for conjoint analysis. The mean of treatments was compared using Tukey's test, considering a 5% probability of type I error. Dunnett's test was used to compare the mean of the additional treatment with the others, considering a 5% probability of type I error, using the Sistemas para Análises Estatísticas e Genética [SAEG] (2003).

Results and Discussion

Chemical composition

The dry matter (DM) content of the forage sampled by cutting was influenced solely by year (P < 0.05). The average DM content was 27.3% and 31.9% for Brachiaria grass and 23.3% and 21.2% for forage peanut, in the first and second year, respectively.

For the samples of intercropped pasture (grass + legume) sampled by hand plucking, the DM content was only affected (P <0.05) by the post-grazing residual heights, with average values of 27.3% and 29.8%, respectively, for residual heights of 5 cm and 15 cm. The higher DM content of Brachiaria grass sampled by cutting in the second year could be attributed to lower precipitation during the plant growth period (Figure 1). Greater rainfall provides more favorable conditions for plant development, reducing stress factors that could lead to changes in the growth pattern (Luo et al., 2020), such as increased senescence rate and tiller death during the regrowth phase and canopy restitution after grazing.

There was an interaction effect (P <0.05) between the year and the post-grazing residual height for the CP content of Brachiaria grass and forage peanut (sampled by cutting) (Figure 2). In the first year, we observed a higher CP content in Brachiaria grass at 5 cm than at 15 cm. However, the CP content was similar between residual heights for Brachiaria grass in the second year. At a lower post-grazing residual height, there was a lower accumulation of senescent material and stems of forage grass. In contrast, for higher post-grazing residual height, this material is greater, causing a reduction in the protein content of the forage (M. E. R. Santos et al., 2011). This discrepancy could explain our observation of lower CP content in the first year for Brachiaria grass managed at 15 cm.

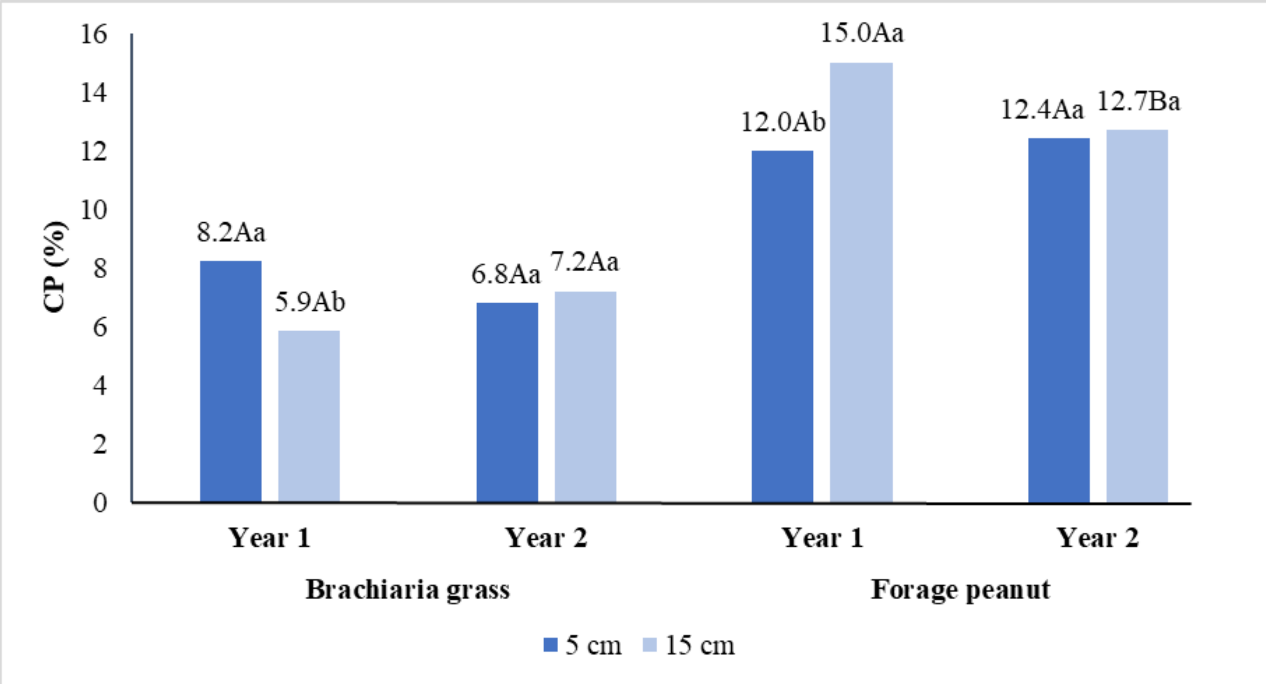

Figure 2. Crude protein (CP) content of Brachiaria grass and forage peanut in two post-grazing residue heights, in two years (sampled by cutting). Uppercase letters are comparing experimental years within post-grazing residue heights. Lowercase letters are comparing the post-grazing residue heights within each experimental year. Means followed by the same letter are not different (P > 0.05) by Tukey's test. Year 1: March to April 2015 and Year 2: March to April 2016.

The turnover of leaves and stolons in forage peanut monocultures under intense defoliation is relatively higher than in other defoliation regimes, resulting in younger plants and a greater proportion of leaves in sward herbage mass. This leads to higher CP content (G. P. Silva et al., 2018). However, in our study, forage peanut intercropped with Brachiaria grass had a higher CP content at 15 cm than at 5 cm in the first year, and we did not observe a difference between residual heights in the second year (Figure 1).

The CP content of forage peanut (sampled by cutting) was affected (P <0.05) by the interaction between row spacing and year (Table 2). There was no difference between the years using the 40 and 50 cm row spacings; however, the 60 cm row spacing had a higher CP content in the first year. A wider row spacing (60 cm) favored the highest crude protein content of forage peanut only in the first year.

Table 2
Crude protein contents of forage peanut in three row spacings, in two years (sampled by cutting)

Year[I]	Row spacing (cm)		
	40	50	60
		Crude protein (%)	
1	12.0Ab	13.1Ab	15.6Aa
2	12.6Aa	12.7Aa	12.5Ba
CV (%)		13.3	

[I]Year 1: March to April 2015 and Year 2: March to April 2016.
CV: coefficient of variation.
Means followed by the same uppercase letters in the columns and lowercase letters in the rows are not different (P > 0.05) by the Tukey test.

There was an interaction effect (P <0.05) between row spacing and post-grazing residual height on the CP content of intercropped pastures sampled by hand plucking (Table 3). Comparing the post-grazing residual heights within the row spacings, we observed higher CP content for the canopy grazed to 5 cm than that grazed to 15 cm with a 50 cm row spacing.

Table 3
Crude protein contents of intercropped pastures (Brachiaria grass + forage peanut), in three row spacings of forage peanut and two post-grazing residue heights, in the second year (sampled by hand plucking)

Post-grazing residue height (cm)	Row spacing (cm)		
	40	50	60
		Crude protein (%)	
5	7.03Ab	8.79Aa	6.49Ab
15	7.30Aa	7.0Ba	7.27Aa
CV (%)		11.9	

CV: coefficient of variation.
Means followed by the same uppercase letters in the columns and lowercase letters in the rows are not different (P > 0.05) by the Tukey test.

There was an interaction effect of the post-grazing height, year, and row spacing (P <0.05) on the neutral detergent fiber corrected for ash and protein (NDFap) content (sampled by cutting; Table 4). The NDFap content ranged from 52.3% to 70.9% for Brachiaria grass and 39.1% to 55.9% for forage peanut. However, the NDFap content of hand-plucking samples (grass + legume) was not affected (P <0.05) by the treatments, with an overall average of 68.8%.

Table 3

Neutral detergent insoluble fiber corrected for ash and protein contents of Brachiaria grass and forage peanut, in three row spacings of forage peanut and two post-grazing residue heights, in two years (sampled by cutting)

Row spacing (cm)	Post-grazing residue height (cm)				CV (%)
	5		15		
	Year[I]		Year		
	1	2	1	2	
	NDFap of Brachiaria grass (%)				
40	66.3AaC	55.0BbCD	70.9AaC	67.1AaC	5.6
50	64.6BaC	59.7AaC	70.0AaC	52.3BbD	
60	65.4AaC	53.3BbD	69.7AaC	67.9AaC	
	NDFap of forage peanut (%)				
40	49.0AaC	39.5AbC	51.3AaC	39.3AbC	9.7
50	55.9AaC	39.1AbC	48.4BaC	44.1AaC	
60	49.3AaC	41.8AbC	53.0AaC	41.2AbC	

[I]Year 1: March to April 2015 and Year 2: March to April 2016.
NDPap: Neutral detergent insoluble fiber corrected for ash and protein.
Means followed by equal letters are not different (P > 0.05) by the Tukey test. A and B compare residue heights within the row spacings and years; a and b compare years within the row spacings and residue heights; C and D compare row spacings within the years of grazing and residue heights.

The CP (Figure 2) and NDFcp (Table 4) contents of Brachiaria grass sampled by cutting were close than those contents obtained for Brachiaria grass intercropped with calopo (*Calopogonium mucunoides* Desv.) and under grazing in a tropical region (Chaves et al., 2021). No results were found for Brachiaria grass intercropping with forage peanut. The highest content of the fibrous fraction was obtained in the first year with a residual height of 15 cm because it may have favored greater participation of stems and senescent material in the forage (Mocelin et al., 2022). Higher NDFap levels of Brachiaria grass and forage peanut in the first year compared to the second (Table 3) can be attributed to climatic conditions (Figure 1) that are more favorable to plant development.

The chemical composition of palisade grass (*Urochloa brizantha*) and forage peanut intercropped was evaluated by Pereira et al. (2015), who observed means of CP and NDFap contents for forage peanut of 25% and 62%, respectively, in which CP content was higher than those found in our study (Tables 2 and 3). However, the experiment was carried out in a locality (South Bahia, Brazil) with more favorable climatic conditions for cultivating forage peanut, which may have favored a more efficient BNF.

The CP contents of samples obtained by hand plucking (Table 3) were closer to those obtained for Brachiaria grass than forage peanut sampled by cutting. The results corroborated the higher percentage of Brachiaria grass in the botanical composition of the pastures, which ranged from 60% to 70%, and probably induced the highest animal selectivity for the Brachiaria grass.

Morphogenetic and structural characteristics

In year 1, the LL, NLL, NDL, LAR, SER, and LSR were not affected (P > 0.05) by the treatments, with means of 19.1 d, 4.47 leaves tiller^{-1}, 1.18 leaves tiller^{-1}, 0.14 leaf tiller^{-1} d^{-1}, 0.36 cm tiller^{-1} d^{-1}, and 0.51 cm tiller^{-1} d^{-1}, respectively.

There was an interaction effect (P <0.05) between row spacing and post-grazing residual heights for FLS, FSS, and LER of Brachiaria grass (Table 5). There was an increase in FSS and LER with increasing row spacing for a post-grazing residual height of 5 cm. LER was higher at 5 cm than at 15 cm when a row spacing of 50 cm was used.

Additionally, the intercropping systems were compared to a Brachiaria grass monoculture; however, there was no difference among the means of treatments for the studied variables (P > 0.05) in the first year (2015), with mean values for FLS, FSS, LL, NLL, NDL, LAR, LER, SER, and LS are 8.13 cm leaf^{-1}, 16.68 cm, 19.3 d leaf^{-1} tiller^{-1}, 4.42 leaf tiller^{-1}, 1.11 leaf tiller^{-1}, 0.13 leaf tiller^{-1} d^{-1}, 1.3 cm tiller^{-1} d^{-1}, 0.38 cm tiller^{-1} d^{-1}, and 0.51 cm tiller^{-1} d^{-1}, respectively.

In year 2, the LAR, SER, and LSR of Brachiaria grass were not affected by the treatments (P > 0.05), with means of 0.1 leaf tiller^{-1} d^{-1}, 0.17 cm tiller^{-1} d^{-1}, and 0.20 cm tiller^{-1} d^{-1}, respectively.

The NLL, NDL, and LER were affected by post-grazing residual heights (P <0.05), with mean values of 3.41 and 3.28 leaves tiller^{-1}, 0.49 and 0.41 leaves tiller^{-1}, and 0.59 and 0.48 cm tiller^{-1} dia^{-1}, respectively, for residual heights of 5 cm and 15 cm.

The means of LER in 2015 and 2016 were approximately three times higher than those of SER, which indicates excellent relative participation of the leaf blade and low contribution of the stem to the growth of the tiller of Brachiaria grass. This demonstrates a favorable characteristic for animals on pasture since the nutritional value of the stems is lower than that of the leaves. Therefore, a higher proportion of leaf blades is desirable in pastures and associated with forage quality and pasture consumption (Geremia et al., 2018).

Table 5

Final leaf size, final stem size, and leaf elongation rate of Brachiaria grass, in the first year, and final leaf size, final stem size, and leaf life of Brachiaria grass, in the second year, in three row spacings of forage peanut and two post-grazing residue heights

Row spacing (cm)	Post-grazing residue height (cm)		CV (%)
	5	15	
	Year 1		
	FLS (cm)		
40	6.57 Ba	9.35 Aa	
50	8.43 Aa	7.62 Aa	
60	8.18 Aa	8.22 Aa	
	FSS (cm)		
40	13.61 Bb	18.01 Aa	
50	13.37 Ba	16.56 Aa	
60	20.14 Aa	16.44 Ab	
	LER (cm tiller^{-1} day^{-1})		
40	1.14 Aa	1.41 Aa	
50	1.46 Aa	1.08 Ab	
60	1.30 Aa	1.29 Aa	
	Year 2		
	FLS (cm)		
40	25.26 Aa	22.67 Ab	
50	23.70 Aa	18.00 Cb	
60	24.00 Aa	20.75 Bb	
	FSS (cm)		
40	16.86 Aa	15.52 Bb	
50	15.93 Ba	16.62 Aa	
60	17.50 Aa	17.35 Aa	
	LL (days leaf^{-1} tiller^{-1})		
40	11.08 Aa	8.88 Ab	
50	11.08 Aa	9.27 Ab	
60	10.82 Aa	6.72 Bb	

[I]Year 1: 01/31/15 a 04/04/15 and year 2: 02/15/16 a 04/27/16.
FLS: final leaves size; FSS: final stem size; LER: leaf elongation rate; LL: leaf life.
Means followed by the same uppercase letters in the columns and lowercase letters in the rows are not different (P > 0.05) by the Tukey test.

The FLS, FSS, and LL of Brachiaria grass were affected (P <0.05) by the interaction between row spacing and post-grazing residual height (Table 5). The FLS values were higher at 5 cm than at 15 cm depth. A residual height of 5 cm provided similar FLS values among the row spacing. However, with a residual height of 15 cm, the FLS values were greater at 50 cm and 60 cm than at 40 cm.

In general, there was an increase in FSS with increasing row spacing for both residual heights. However, there was a difference between the FSS values obtained at 5 cm and 15 cm in the 40 cm row spacing.

A post-grazing residual height of 5 cm provided a higher LL than that of 15 cm for all row spacings. Furthermore, the LL values were similar among the row spacings at a residual height of 5 cm. In contrast, at 15 cm, the lowest LL was observed at 60 cm row spacing.

The LER was affected by the row spacings (P <0.05), with 0.60 (a), 0.55 (b), and 0.60 (c) cm tiller-1 day1, respectively, for 40, 50, and 60 cm.

Most of the studied variables were not affected by the post-grazing residue heights. T. C. da Silva et al. (2012) did not find differences in morphological and structural characteristics when comparing Brachiaria grass in monoculture cut at post-grazing residue heights of 15 and 25 cm. A consistent positive effect of the canopy managed at 5 cm post-grazing residual height on FLS, and LL was observed in the second year (Table 6). These results may be associated with the leaf area recovery dynamics at a higher intensity of defoliation (Martins et al., 2021).

Table 6

Means of final stem size, number of live leaves, leaf elongation rate, final leaf size, and leaf life of a monoculture of Brachiaria grass and of Brachiaria grass in three row spacings of forage peanut and two post-grazing residue heights, in the second year

Treatment	FSS (cm)	NLL (leaf tiller^{-1})	LER (cm tiller^{-1} day^{-1})	FLS (cm leaf)	LL (day leaf^{-1} tiller^{-1})
ControlI	18.47	3.07	0.42	15.85	7.55
40-5II	16.83**	3.44**	0.65**	25.18**	11.14**
40-15	15.52**	3.25	0.45	22.67**	8.87**
50-5	15.89**	3.38**	0.62**	23.62**	11.14**
50-15	16.62**	3.35**	0.60**	18.00**	9.27**
60-5	17.50**	3.47**	0.55**	24.00**	10.82**
60-15	17.35**	3.25	0.40	20.75**	6.72
CV (%)	2.7	4.6	12.5	4.6	6.5

FSS: Final stem size; NLL: number of live leaves; LER: leaf elongation rate; FLS: final leaves size; LL: leaf life.
[I] Control = monoculture of Brachiaria grass.
[II] Combination 40; 50 and 60 cm row spacings and residue heights of 5 and 15 cm.
Means followed by ** differ from control at the 5% probability level by the Dunnet test.

In pastures under intermittent stocking, defoliation intensity is an important regulator of the light environment of the plants. Therefore, under higher grazing intensities, basal buds are stimulated by light. The regrowth occurs mainly through the development of new tillers, which prioritize the reconstitution of leaf area over stem lengthening. In contrast, under lower defoliation intensities, regrowth occurs mainly from the remaining leaves and axillary buds, and greater competition for light occurs, which can stimulate the development of stems at the expense of the leaf blades (M. E. R. Santos et al., 2011). However, in this study, a residual height of 15 cm favored stem lengthening (FSS) only at 40 cm row spacing in the first year, probably because of greater competition with forage peanut at this spacing. However, in year 1, the residual height of 15 cm reduced the FSS at the 60 cm spacing (Table 5).

Additionally, the intercropping systems were compared to a Brachiaria grass monoculture, and no difference was observed among the averages for NDL, LAR, SER, and LSR, with means of 0.44 leaf tillers^{-1}, 0.10 leaf tiller^{-1} d^{-1}, 0.17 cm tiller^{-1} d^{-1}, and 0.20 cm tiller^{-1} d^{-1}, respectively. However, FLS, FSS, LL, NLL, and LER were affected ($P < 0.05$) by the treatments (Table 6). Higher values of FLS ($P < 0.05$) and smaller values of FSS ($P < 0.05$) were observed for all row spacing–residue height combinations compared to a Brachiaria grass monoculture. In general, higher LL ($P < 0.05$), NLL ($P < 0.05$), and LER ($P < 0.05$) values were recorded in the intercropping systems than in the Brachiaria grass monoculture.

The intercropping treatments showed superior structural and morphogenic characteristics compared to a Brachiaria grass monoculture used as a control (Table 6). These results can be attributed mainly to the introduction of nitrogen-fixing species, showing the potential of these systems for the recovery of degraded Brachiaria grass pastures. According to Thilakarathna et al. (2016), the amount of N transferred to the grass below ground was estimated to be 3–102 kg N ha^{-1} year^{-1}, predominantly through the decomposition of legume roots and nodules.

The better morphogenic and structural characteristics observed for Brachiaria grass in year 1 than in year 2 may be attributed to higher rainfall during the evaluation period (Figure 1).

Tillering dynamic

There was a variation ($P < 0.05$) in the tiller population according to the season of the year, from 97.3 tillers plant^{-1} in the dry season to 120 tillers plant^{-1} in the rainy season. Similarly, the TMR ranged ($P < 0.05$) from 0.0018 to 0.0028 tillers/100 tillers d^{-1} in the respective seasons.

The treatments did not significantly affect the tiller emergence rate and tiller population stability index ($P > 0.05$), with averages of 0.0048 tillers/100 tillers d^{-1} and 1.0025 tillers/100 tillers d^{-1}, respectively. Despite our expectations, we did not observe an effect of grazing intensity on tiller density, and results with grass-legume intercropping are scarce.

The variations observed in the population and mortality rate of tillers across seasons are associated with environmental conditions, such as temperature and precipitation, and correspond to the rainy season. The favorable conditions for plant growth and development result in higher tiller appearance and mortality rates. The higher tiller population is associated with population stability, indicating a partial renewal of the population.

Population stability index values lower than 1.0 indicate that the population and the appearance of new tillers are not enough to compensate for mortality rates and that a population would tend to decrease. In contrast, values greater than 1.0 indicate the opposite situation, while values close to 1.0 indicate a stable dynamic equilibrium (Bahmani et al., 2003). In this study, the tiller population remained stable, demonstrating no loss of tillering potential between seasons with consequent productive stability.

Conclusions

Forage peanut improve the morphogenic and structural characteristics of Brachiaria grass, primarily when managed with a post-grazing height of 5 cm, which improves the chemical composition. Additionally, based on these analyses, any of the three row spacings (40 cm, 50 cm, and 60 cm) is recommended. Finally, higher tiller populations and Brachiaria grass tiller mortality rates were obtained in the rainy season than in the dry season.

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