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Productive traits and nutritional value of *Urochloa ruziziensis* submitted to different planting densities and defoliation intensities

[*Características produtivas e valor nutritivo de* Urochloa ruziziensis*, submetida a diferentes densidades de plantio e intensidades de desfolha*]

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ABSTRACT

The aim of this study was to evaluate the forage mass and accumulation and nutritional value of cultivars Kennedy and BRS Integra (*Urochloa ruziziensis*), subjected to two planting densities (15 and 30 plants/m^2) and three stubble height (15, 30 and 40 cm). The experimental design was a randomized block, in a 2x2x3 factorial, with three replications. The experimental period comprised two agrostological years. Plants managed under lower stubble height (15cm), showed lower leaf:stem ratio and higher canopy heights at harvest, based on the light interception of 95%. The highest forage mass was observed to cultivar BRS Integra under lower planting density (15 plants/m^2). The two cultivars showed high nutritive value, without influence of studied factors. In general, the cultivars were similar for most variables studied. Planting with 15 plants/m^2 and moderate defoliation (30cm residue) resulted in higher forage accumulation, especially in the second year after planting. These targets are suggested for the management of *U. ruziziensis* cultivars.

Keywords: BRS Integra, chemical composition, forage accumulation, forage mass, stubble height

RESUMO

*O objetivo deste trabalho foi avaliar a massa e o acúmulo de forragem e o valor nutritivo das cultivares Kennedy e BRS Integra (*Urochloa ruziziensis*), submetidas a duas densidades de plantio (15 e 30 plantas/m^2) e três alturas de desfolha (15, 30 e 40 cm). O delineamento experimental foi o de blocos ao acaso, em esquema fatorial 2x2x3, com três repetições. O período experimental compreendeu dois anos agrostológicos. Plantas manejadas com a menor altura de resíduo (15cm) apresentaram menor relação folha:colmo e maior altura no momento do corte, com base na interceptação luminosa de 95%. A maior massa de forragem foi observada para a cultivar BRS Integra sob menor densidade de plantio (15 plantas/m^2). As duas cultivares apresentaram elevado valor nutritivo, sem influência de nenhum fator. De forma geral, as cultivares foram similares para a maioria das variáveis estudadas. O plantio de 15 plantas/m^2 e a desfolha moderada (resíduo de 30cm) resultaram em maior acúmulo de forragem, principalmente no segundo ano após o plantio, sendo essas as metas de manejo recomendadas para as cultivares de* U. ruziziensis.

Palavras-chave: acúmulo de forragem, altura de resíduo, BRS Integra, composição química, massa de forragem

INTRODUCTION

Plants of the genus *Urochloa* (syn. *Brachiaria*) are important forages for animal production systems in the world, contributing to the largest area of cultivated pastures in Brazil in relation to other forages (Valle *et al*., 2022). The species *U. ruziziensis* is recognized as having the highest nutritional value, presenting higher crude protein and lower fiber levels when compared to other species of the genus (Lopes *et al*., 2010; Valle *et al*., 2022). Additionally, it has the greatest

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potential for use in integrated crop-livestock systems due to its ease of desiccation and adaptation to over-sowing (Souza Sobrinho *et al.*, 2016).

Nonetheless, the species present high susceptibility to pasture spittlebugs, especially those of the genera *Deois* and *Notozulia*. Spittlebug infestation is one of the main obstacles of *U. ruziziensis* pasture management, due to the reduction of dry matter production and nutritional value (Souza Sobrinho *et al*., 2010).

The breeding of tropical forages, such as of the genus *Urochloa*, is underway to help producers overcome some biotic and abiotic limitations, such as the spittlebug susceptibility, that limits these species productivity in Brazilian livestock systems (Valle *et al*., 2022). A new cultivar of *U. ruziziensis* (BRS Integra) was launched in 2022 by Embrapa. This cultivar presents a higher productivity and provides greater resistance to pasture spittlebugs compared to the only cultivar available on the market (cv. Kennedy). Although the new cultivar is promising, the application of appropriate management practices can impact its success in animal production systems. In this sense, Fonseca *et al*. (2022) highlight the importance of knowledge and correct application of forage plant management for the success of the production system.

One key management decision is the planting density of the forage. Success in pasture establishing depends, initially, on the number of plants established per unit of soil area. Although there is no specific recommendation for *U. ruziziensis*, and more specifically for the cultivar BRS Integra, some authors suggest densities ranging from 8 to 40 plants/m^2 for *U. humidicola* and *U. brizantha* (Obeid *et al*., 1995; Valle *et al*., 2022).

The stubble height is another critical management factor, due to its influence on dry matter production, forage quality and pasture persistence (Gomide *et al*., 2014). The forage plants show phenotypic plasticity, characterized by a certain adaptation to different defoliation intensities (Lemaire and Chapman, 1996). Typically, the defoliation severity that has been most suitable for tropical grasses represent a removal of approximately 50% of the pre-grazing condition (Sbrissia *et al*., 2018), but the use of different defoliation intensities can be useful, depending on time of year and the forage species (Silva and Nascimento Junior, 2007).

The aim of this study was to evaluate productive traits and nutritive value of the new cultivar BRS Integra, in comparison to traditional *U. ruziziensis* cultivar (Kennedy), established at two planting densities and submitted to three stubble heights.

MATERIALS AND METHODS

The experiment was performed at the Experimental Farm of the Embrapa Dairy Cattle, in the city of Coronel Pacheco, Minas Gerais, Brazil (21°33'22'S and 43°06'15 "O; 410 m), from December 2017 to July 2019. The climate of the region is classified as Cwa (mesothermal) according to the Classification Köeppen-Geiger (Peel *et al*., 2007). The climatic data over the experimental period were collected at the automatic meteorological station of the National Institute of Meteorology (INMET) located 300 m from the study site (Figure 1).

The soil of the experimental plots is Dystrophic Red-Yellow Latosol type with clayey texture (Brazilian…, 2013). For the chemical characterization, soil samples were collected from the 0-20cm at the beginning of the experiment. The soil chemical characteristics were pH (water) 5.0; phosphorus (Mehlich-1), 8.9mg/dm^3; potassium, 92mg/dm^3; calcium, 1.6cmolc/dm^3; magnesium, 0.5cmolc/dm^3; aluminum, 0.2cmolc/dm^3; H + Al, 4.46cmolc/dm^3; base saturation (V%), 34% and organic matter, 3.1 mg/dm^3.

The plots (3 x 2m) were established in November 2017 in an area of approximately 460 m^2, through seedling planting. Seedling production was carried out in a greenhouse and after emergence, the seedlings were transplanted into the field plots. Phosphate fertilization was applied at planting, at a rate of 80 kg/ha P_2O_5. The experimental period comprised two consecutive agrostological years (rainy season), 2017/2018 (Year 1) and 2018/2019 (Year 2). Fertilization was performed after each harvest event with 40 kg/ha of N and K_2O and 10 kg/ha of P_2O_5 (commercial fertilizer, NPK 20-05-20).

The treatments were distributed in a randomized complete block design with three replicates, in a 2x2x3 factorial arrangement. The treatments consisted of two *U. ruziziensis* cultivars (BRS Integra and Kennedy), two planting densities (15 and 30 plants/m^2) and three stubble height (15, 30 and 40 cm), totaling 36 experimental units of 6.0 m^2 each (3 x 2m).

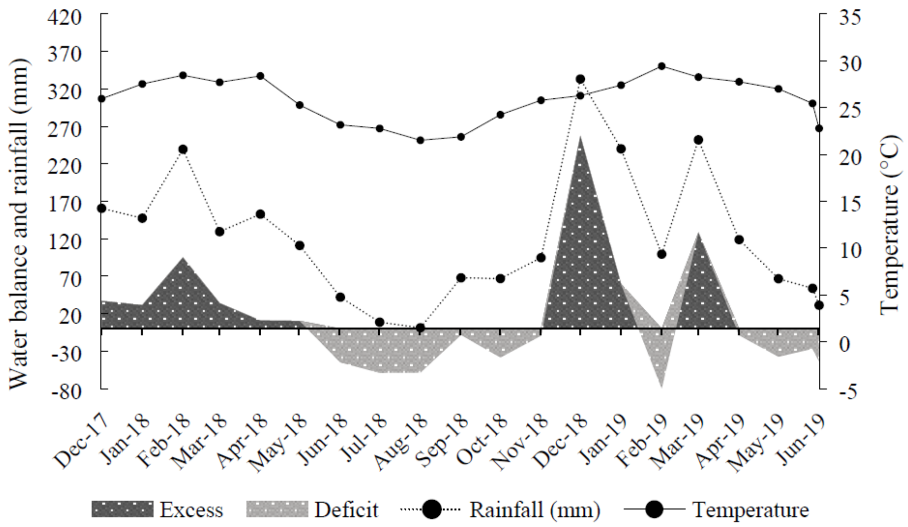

Figure 1. Water balance and climate data over the period.

Forage mass was evaluated during each growth cycle whenever the canopy reached 95% light interception (LI). LI was measured once a week, at four points of each plot, with a DECAGON Accupar LP 80 device (USA). Once the proposed light interception was achieved, three height measurements of the forage canopy were taken to associate with the 95% light interception criterion. The plants were cut to predetermined stubble heights according to estimated forage mass. For sampling, a frame with an area of 0.5m² (1 x 0.5m) was used at a representative point of the average height of the plot. All the forage mass above the stubble height was harvested and placed in identified plastic bags. The samples were then sent to the laboratory and the weight was recorded. A subsample of approximately 400 g was removed to count the number of tillers and to estimate the tiller population density. The morphological components were separated by leaf, stem (stem + sheath) and dead forage mass.

After separation, the material was placed in paper bags, dried in a forced-air ventilation oven at 55°C for 72 hours to determine the dry matter (DM) content and subsequent estimation of forage mass, calculated as the sum of the values of each morphological component, converted to kg/ha of DM. A second subsample was used to evaluate the nutritive value of the forage. After drying, the material was ground through a Wiley mill to pass through to 1 mm screen sieve and stored in plastic containers until nutritional analysis. The forage accumulation was calculated by the sum of the forage mass obtained above the desired stubble heights, from each cutting during the experimental period. Forage accumulation rate was calculated by dividing the forage mass by the number of days between the samplings (intervals between cuts).

The determination of the chemical composition and *in vitro* DM digestibility (IVDMD) was performed at the Animal Nutrition Laboratory of Embrapa Dairy Cattle (Juiz de Fora, Minas Gerais – Brazil), in samples collected above the desired stubble heights. The total nitrogen content was analyzed according to the Kjeldahl procedure (Official…, 1990). The crude protein content (CP) was calculated as total N × 6.25. The neutral detergent fiber (NDF) content, acid detergent fiber (ADF) and lignin were analyzed according to the methodology described by Van Soest *et al*., (1991). The IVDMD was determined according to the technique described by Tilley and Terry (1963).

For the variance analysis (ANOVA) there was considered to the following fixed effects model:

Yijklr = μ +Bl+ Ck + Aj + Di+ CAkj+ CDki+ ADji +CDAijk+ eijklr

Where: Y_{ijklr} = observation in replicate r, in block 1, cultivar k, height j, density i; μ = general mean; B_l = block effect 1; C_k = effect of cultivar i; A_j =height effect j; Di = effect of density i; CA_{kj} = fixed effect of the interaction between cultivar k and height j; CD_{ik} = fixed effect of the interaction between cultivar k with density i; AD_{ji} = fixed effect of the interaction between height j with density i; CDA_{ijk} = effect of the interaction between cultivar, height and density; e_{ijklr} = random error associated with each observation. Each year was analyzed separately.

To compare the means of experimental groups, the *post hoc* Tukey's test was used with significance declared at $P \leq 0.05$. The data was analyzed using the lm procedure in R (R Core Team, 2019).

RESULTS

Regardless of cultivar and plant density, the defoliation severity, characterized as the % reduction in pre-cutting height, was greater with a residue of 15cm, intermediate in the residue of 30cm and lower in the residue of 40cm. The defoliation interval was greater with 15cm and lower with 40cm of residue. Consequently, the number of cuts was inversely proportional to the severity of defoliation (Table 1).

Table 1. Defoliation severity (relative to pre-cutting height), defoliation interval and number of cuts in *Urochloa ruziziensis*, submitted to different stubble heights, in two experimental years.

Characteristics	Stubble height (cm)					
	15	30	40	15	30	40
	2017/2018			2018/2019		
Defoliation severity (%)	76	51	42	82	55	45
Defoliation interval (days)	30	22	18	49	34	32
Cut numbers	4.0	6.0	6.3	3.0	5.5	5.5

In year 1, there was an interaction between planting density and stubble height (Fig. 2) for sward height (P = 0.0015; SEM = 1.15). Considering the density of 15 plants/m2, the lowest sward canopy height was observed with the stubble height of 30 cm. For 30 plants/m^2, the lower sward canopy height was observed at the stubble height of 15cm, and did not vary between the stubble height of 30 and 40 cm. For the 15 cm stubble height, the greatest canopy height was observed in the density of 15 plants/m^2.

In the second experimental year, the sward height was not affect by studied factors with average value of 74.5cm.

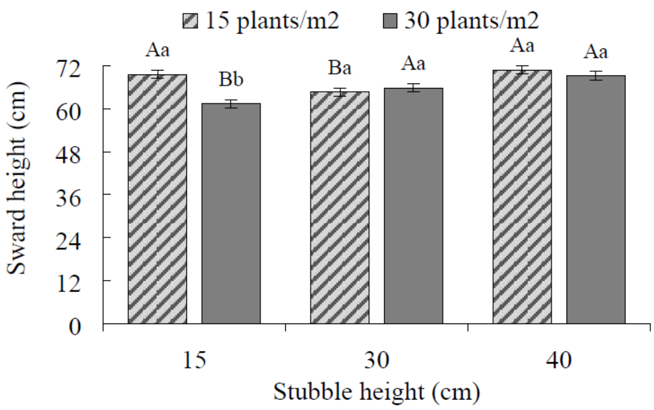

Figure 2. Sward canopy height of *Urochloa ruziziensis*, according to stubble height and plant density, in the agrostological summer 2017/2018. Means followed by capital letters compare stubble heights and lowercase letters compare planting densities.

The leaf:stem ratio was affected by cultivar, plant densities and stubble height in the first year of evaluation. BRS Integra had greater value than Kennedy (*P* < 0.01; SEM = 0.08; Fig. 3A); and the plant density of 30 plants/m^2 presented greater value than 15 plant/m^2 (*P* < 0.01; SEM = 0.08; Fig. 3 B). In relation to the defoliation severity, higher leaf:stem ratio was observed for the 40 cm stubble height (*P* < 0.01; SEM = 0.09; Fig. 3 C).

In year 2, no difference was observed between cultivars and planting densities. However, there was a significant effect of stubble heights (*P* = 0.0001; SEM = 0.13), with leaf:stem ratio increasing with the stubble height (Fig. 3 D).

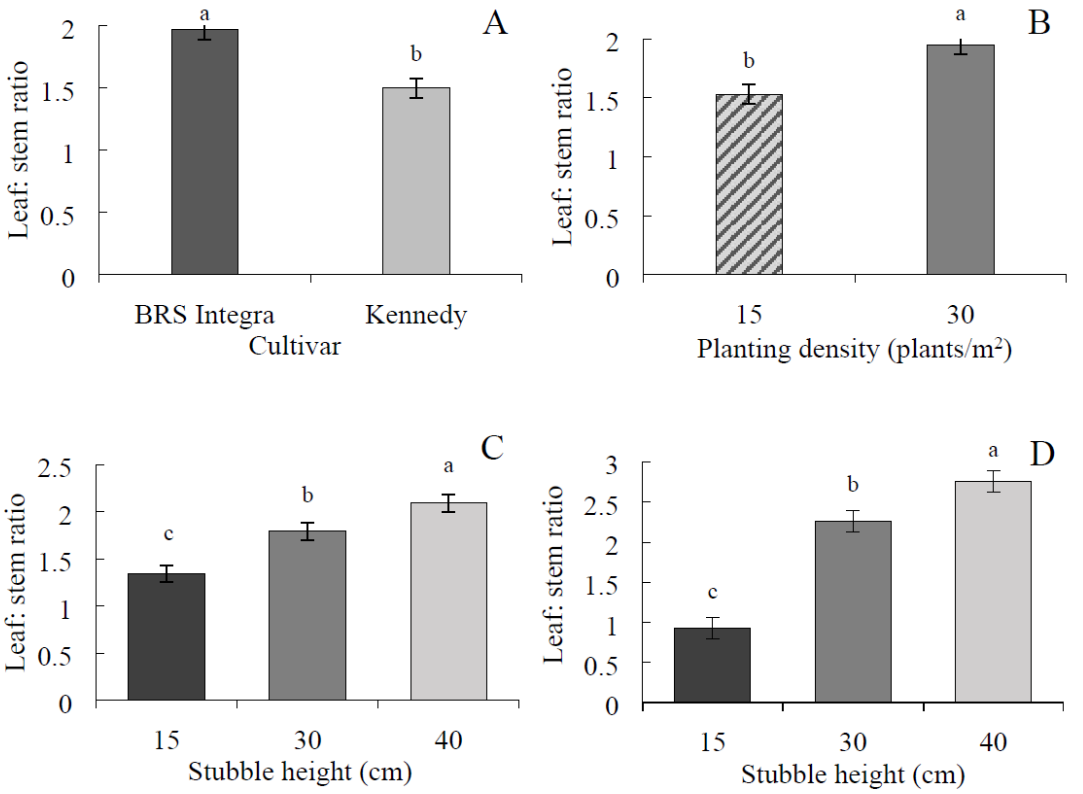

Figure 3. Leaf:stem ratio of *Urochloa ruziziensis*, according to cultivar (A), planting density (B) and stubble height (C), in the agrostological summer 2017/2018 and stubble height (D), in the agrostological summer 2018/2019. Lowercase letters between columns represent a significant difference between treatments.

In the first year, there was an interaction between cultivar and planting density for tiller density (*P* = 0.0192; SEM = 29.82), forage mass (*P* = 0.0451; SEM = 84.33), leaf mass (*P* = 0.0114; SEM = 46.62), stem mass (*P* = 0.0329; SEM = 47.04) and dead material (*P* = 0.0496; SEM = 6.11). In general, BRS Integra showed higher values for these variables at the density of 15 plants/m^2, when compared to planting with 30 plants/m^2. The cultivar Kennedy did not show differences between planting densities for these variables, except for stem mass, with was greater at the density of 15 plants/m^2. (Fig. 4 A, B, C, D and E).

There were higher values of tiller density, forage mass and stem mass for the cultivar Kennedy in relation to the BRS Integra at the 30 plants/m^2 (Fig. 4 A, B and D). The leaf mass was higher in BRS Integra than in Kennedy, with 15 plants/m^2 and did not vary with the cultivar in the plant density of 30 plants/m^2 (Fig. 4 C). In addition, the values for dead material were lower in BRS

Integra than Kennedy at 15 plants/m^2 and similar between cultivars at the 30 plants/m^2 (Fig. 4 E).

In the second year, none of the factors influenced the tiller density, forage mass and its components (leaf, stem, and dead mass). The average values observed were: 430 tiller/m^2 and 2301, 1123, 1059 and 119 kg DM/ha for forage mass, leaf mass, stem mass e dead material, respectively.

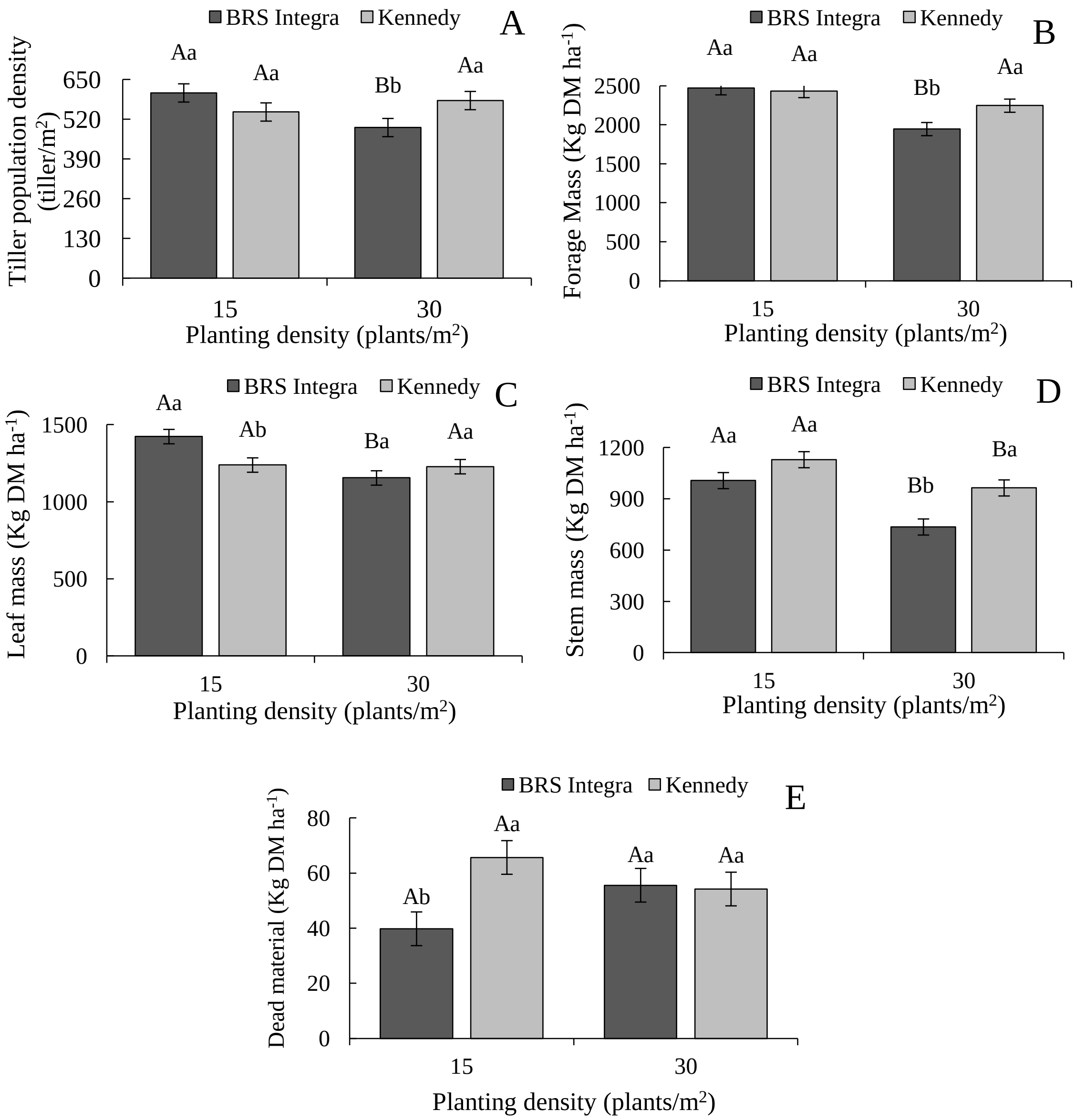

Figure 4. Tiller population density (A), forage mass (B), leaf mass (C), stem mass (D) and dead material (E) of *Urochloa ruzizienis* in the agrostological summer 2017/2018. Means followed by capital letters compare planting densities and lowercase letters compare cultivars. Comparisons were performed by the *post hoc* Tukey's test at 5% probability.

There was no effect of cultivar for the forage accumulation rate. However, in both years, there was an interaction between plant density and stubble height (*P* = 0.0031; SEM = 4.59) for the variable forage accumulation rate. In the first year, differences between plant densities were observed only for those with the lowest stubble height (15 cm). In the density of 15 plants/m^2, the highest and the lowest accumulation rates were observed with 15 and 30 cm of stubble height, respectively, and there was no difference with 30 plants/m^2 (Fig. 5 A).

In the second year, lower forage accumulation rate was observed under the stubble height of 40cm, regardless of planting densities (Fig. 5B). Difference between plant density occurred only in the 30 cm stubble height, with lower forage accumulation rate for the density of 15 plants/m^2.

For the forage accumulation, there was an interaction between cultivar and stubble height (*P* = 0.0001; SEM = 547.30). In the first year, the value was lowest at 15cm of stubble height, for the cultivar BRS Integra, while for the cultivar Kennedy, the lowest value was found at 40cm of stubble height. The forage accumulation was similar between the cultivars at 30cm of stubble height but was higher for Kennedy at 15 cm and for BRS Integra at 40cm of stubble height (Fig. 6 A).

In the second year, for both cultivars, the forage accumulation was higher at stubble height of 30cm. Forage accumulation was higher for BRS Integra at 15cm and for Kennedy at 30cm of stubble height. No difference between cultivars was observed at 40cm of stubble height (Fig. 6 B).

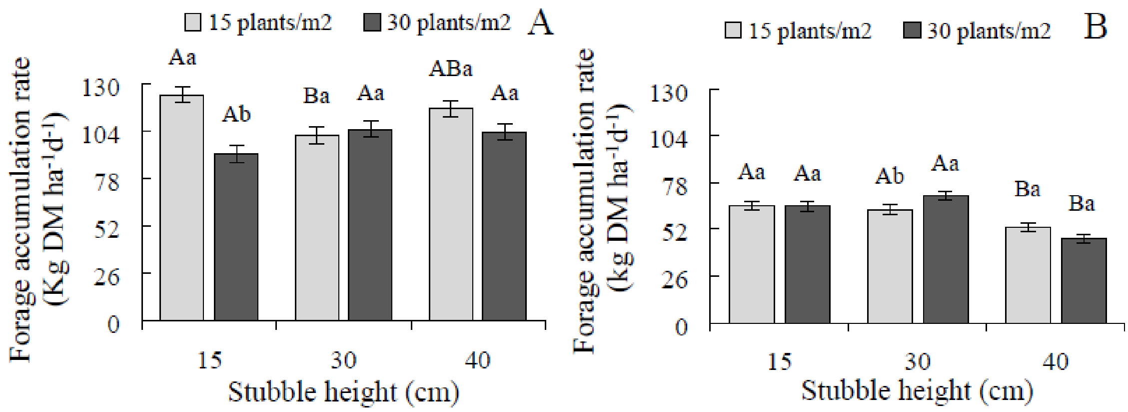

Figure 5. Forage accumulation rate of *Urochloa ruziziensis*, according to stubble height and planting density, in the agrostological summer 2017/2018 (A) and 2018/2019 (B)
Means followed by capital letters compare stubble height and lowercase letters compare planting densities. Comparisons were performed by the *post hoc* Tukey's test at 5% probability.

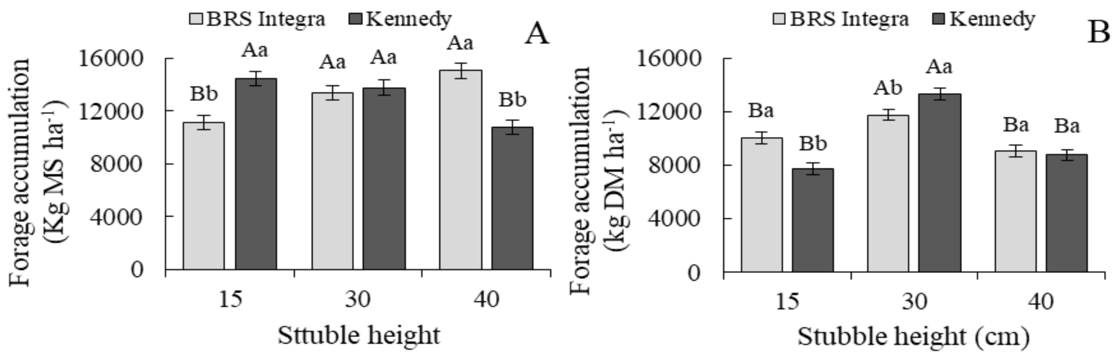

Figure 6. Forage accumulation of *Urochloa ruziziensis*, according to cultivar and stubble height, in the agrostological summer 2017/2018 (A) and 2018/2019 (B). Means followed by capital letters compare stubble height and lowercase letters compare cultivar. Comparisons were performed by the *post hoc* Tukey's test at 5% probability.

In addition, there was an interaction between planting density and stubble height (P = 0.0001; SEM = 424.55) for forage accumulation. In the first year, the values did not vary among stubble heights, with 15 plants/m^2, while it was higher at 30cm of stubble height, with 30 plants/m^2. At 15 and 40cm of stubble height, the higher forage accumulations were observed with density of 15 plants/m^2, while with 30 plants/m^2, no difference was observed (Fig. 7A). In the second year, the higher forage accumulation was verified at 30 cm o stubble height, regardless of planting density. The effect of planting density followed the same pattern from the first year, with higher forage accumulation for the lower plant density 15 plants/m^2, at 15 and 40 cm. No difference between plant densities, at 30 cm of stubble height (Fig. 7B).

There was no effect of the studied factors or their interactions on the bromatological composition of the harvested forage. The means values were CP, 161.5g/kg; NDF, 577.5g/kg; ADF, 307.5g/kg; Lignin, 24.8g/kg and IVDMD, 672.5g/kg.

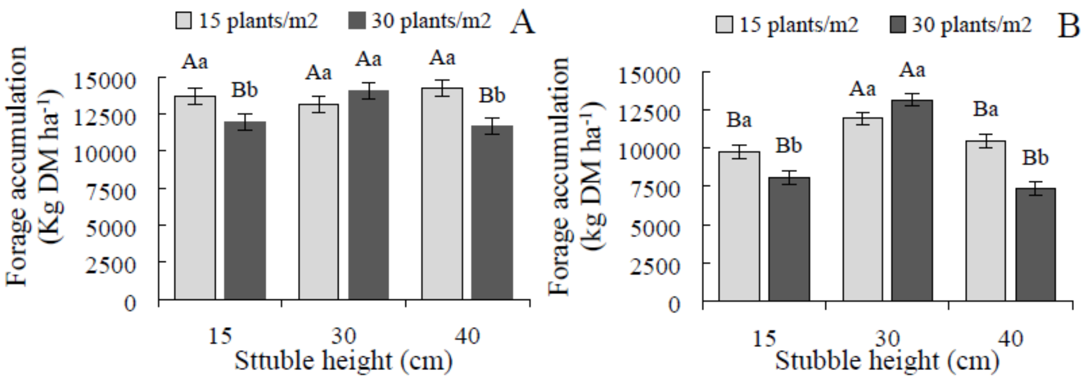

Figure 7. Forage accumulation of *Urochloa ruziziensis*, according to planting density and stubble height, in the agrostological summer 2017/2018 (A) and 2018/2019 (B). Means followed by capital letters compare stubble height and lowercase letters compare planting densities. Comparisons were performed by the *post hoc* Tukey's test at 5% probability.

DISCUSSION

The use of the critical leaf area index that correspond to the light interception of 95% by the canopy has been validated for several tropical grasses (Silva, 2013) The lowest residue height resulted in an increase in the interval between cuts based on the 95% light interception by the canopy. Consequently, fewer growth cycles were obtained compared to the stubble height of 30 and 40cm (Table 1). Furthermore, the harvest forage of plants managed under severe defoliation showed a decrease in leaf proportion and an increase in stem proportion, which can negatively affect animal consumption (Fonseca *et al*., 2013).

Intermediate and lenient defoliations (30 and 40cm stubble height, respectively), showed proportion of defoliation between 40 and 50%, with similar cut intervals (Table 1). According to Sbrissia *et al*. (2018), pastures managed with a lowering of up to 50%, have a high leaf percentage and a low stem fraction, as 90% of stems are in the lower half of pasture layer. When evaluating the lowering of 40 and 70% in ryegrass pastures, Schons *et al*. (2021) observed three times more defoliation cycles and higher leaf:stem ratio in pasture undergoing lower defoliation. Pasture structure resulting from defoliation process affects the subsequent grazing process, representing a continuous cycle of cause-effect relationship.

The greatest tiller population density observed in the lowest planting density (Fig. 4 A) for BRS Integra cultivar, is associated with greater forage, leaf, and stem mass (Fig. 4 B, C and D), since the tiller density is a determinant variable of pasture structure (Lima *et al*., 2018). The greatest forage mass observed under low planting density demonstrated the importance of radiation level for basal tillage, since there is a reduction in selfshading effect in the forage canopy, minimizing the light competition (Santos *et al*., 2011).

The forage mass was also affected by stubble height. The higher the stubble height the lower the harvest efficiency, that is, the lower the amount of forage mass harvested in relation to the total mass. Pastures lowered to 15cm, resulted in a decrease of approximately 70% of canopies heights, compared with 50 and 40% for stubble height of 30 and 40 cm, respectively (Table 1). Consequently, it resulted in a longer interval between cuts. A possible explanation of this result is a reduction in leaf elongation due to the damage caused in part of meristems (Gastal and Lemaire, 2015). The most severe defoliation removed a greater forage amount and was responsible for higher forage mass values in lowest residue. The highest sward canopy height observed, under lower stubble height (15cm), may be related to longer defoliation interval (30 days), which consequently leads to the reduction in leaf:stem ratio. When submitted to longer defoliation intervals, forage canopies tend to intercept light with less efficiency, since the leaves under this management have lower individual potential for photosynthetic assimilation (Pedreira *et al*., 2007). In addition, the lower leaf/stem ratio, under lower residue, may be related to the lower cutting height, which determines a forage mass with a higher percentage of stems. Therefore, we suggest that *U. ruziziensis* cultivars should be managed under lower leaf area index, that is, below that considered critical (less than 95% IL), which would correspond to the intermediate or high stubble height (30 or 40 cm) and more frequent harvests.

The increase of the leaf area index results in higher stem elongation due to shading of basal leaves and consequent increase the senescence process (Silva *et al*., 2013). It is worth mentioning that the higher stem production is not a desired factor in forage canopies since it has a negative relationship with plant nutritional value (Silva *et al*., 2015), being a physical barrier during the grazing process (Savian *et al*., 2018). Sward management with LI below 95%, could be a tool to control the high stem percentage during the regrowth period (Silva and Nascimento Jr., 2007). However, in this study forage nutritive values were not impacted by the management factors tested.

The forage accumulation rate varied according to the plant densities. Lower planting density (15 plants/m^2) provided greater forage accumulation rate for all stubble height. It can be justified by the greater light incidence at the sward base, providing a stimulus for tillering (Santos *et al*., 2011). The Kennedy cultivar, when established with 30 plants/m^2, showed a lower forage accumulation rate in the second year, compared to BRS Integra. This result indicates that Kennedy cultivar does not adapt under greater planting density. This result confirms, to a certain extent, the hypothesis that a higher planting density would favor the cultivar BRS Integra due to its more vertical growth habit in relation to Kennedy. The forage accumulation rate in this study was still greater than those observed in previous studies with tropical forages (Euclides *et al*., 2016; Sbrissia *et al*., 2018).

Lower stubble heights require more time to reach the optimal defoliation point, 95% IL and, consequently, they have greater forage mass. On the other hand, the greatest portion of this total forage mass is composed of stems and dead material, since leaf accumulation stabilizes or decreases, causing a significant increase in senescence and stem elongation processes (Silva *et al.*, 2013).

During the second experimental year, greater forage accumulation was observed for stubble height 30 cm, indicating that severe and lenient defoliation negatively influenced the forage accumulation. Silveira *et al*. (2016) observed similar result in study with Mulato grass (*Urochloa hybrid ssp*) under rotational strategies managements.

Forage accumulation in pastures is resulted of multiples processes and interactions that occur on the sword. During both experimental years, greater stability of forage accumulation was observed in the intermediate defoliation severity (stubble height 30 cm), with similar or superior values in comparison to the other stubble height (15 and 40 cm), indicating that severe and lenient defoliation negatively influences the forage accumulation (Silveira *et al*., 2016).

It is known that *U. ruziziensis* has better nutritional quality when compared to other species of *Urochloa* genus, such as *U.*

decumbens, *U. humidicola* and *U. brizantha* (Lopes *et al*., 2010). Our results confirm the high nutritional value of the species, with no difference in chemical composition between cultivars. Moreira *et al*. (2018) also reported high nutritional value when they evaluated nutritional diversity of *U. ruziziensis* clones from Embrapa's breeding program, under severe defoliation (10cm).

However, the absence of an effect of stubble height on chemical composition and IVDMD was surprising, considering the marked difference in leaf and stem proportion in the forage mass harvested at different stubble heights. The improved nutritional value would be expected under more lenient defoliation, which presented a greater leaf proportion and lower nutritional value in the most severe defoliation, where stem proportions were greater. Although chemical analysis of isolated fractions (leaf blades and stems) was not performed, the similarity of the results in the different residues points to a high nutritional value of *U. ruziziensis* stems. Another possible explanation may come from the criterion for separating the leaf and stem morphological fractions. The leaf blade was considered a leaf, and the entire portion below the leaf ligule was computed as a stem. Thus, in forage samples collected above a predetermined residue, as in the present study, part of the mass considered as stem is composed of pseudostem, in addiction to young stems, which have a high nutritive value, with high IVDMD coefficients and CP contents (Queiroz *et al*., 2000; Paciullo *et al*., 2001).

CONCLUSION

Cultivars were similar for most traits evaluated. However, BRS Integra stood out for the highest leaf/stem ratio in the first year. The nutritional value of *U. ruziziensis* cultivars is considered high, regardless of planting density and severity of defoliation. The planting density with 15 plants/m^2, associated to moderate defoliation (30 cm residue), representing a severity of approximately 50%, provided greater forage accumulation. For this reason, these targets are suggested for the management of cultivars.

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