https://doi.org/10.22319/rmcp.v12i3.5742

Article

Structure of forage sward with *Urochloa brizantha* cultivars under shading

Estella Rosseto Janusckiewicz [a]*

Luísa Melville Paiva [a]

Henrique Jorge Fernandes [a]

Alex Coene Fleitas [b]

Patricia dos Santos Gomes [a]

[a] State University of Mato Grosso do Sul. University Unit of Aquidauana, Rodovia Graziela Maciel Barroso, Km 12 Zona Rural, 79200000, Aquidauana, MS, Brazil.

[b] Federal University of Mato Grosso do Sul. Faculty of Veterinary Medicine and Animal Science, Campo Grande, MS, Brazil.

* Corresponding author: estella_rosseto_janusckiewicz@yahoo.com.br

Abstract:

This study evaluated the structure of swards planted with *Urochloa brizantha* cv. BRS Paiaguas and BRS Piata under the eucalyptus shading system, fertilized via foliar at the beginning of the dry and rainy seasons. The experiment followed a randomized block design with a 4×2×2 (4 leaf fertilizer levels × 2 systems × 2 seasons) factorial arrangement. The results were analyzed using the GLIMMIX PROC of SAS University while means were compared by the T-test at 5%. Foliar fertilizer had a significant (P≤0.05) effect on cv. BRS Paiaguas stem mass under shading while the 3 and 6 L/ha levels produced the lowest (P≤0.05) masses. The forage and root masses were not significantly affected (P≥0.05) by the systems and seasons whereas the dead material mass was not influenced by the seasons. The shading system resulted in (P≤0.05) significantly lower dead material mass for both cultivars and higher (P≤0.05) leaf and stem masses for the cv. BRS Piata. In the rainy season, leaf and stem masses were greater (P≤0.05). Foliar fertilization up to 6 L/ha favored the stem control in cv. BRS Paiaguas under shading. The resulting masses of forage, dead material, and root allow concluding that the cultivars adapted well to the shading and dry season.

Key words: *Brachiaria brizantha*, Foliar fertilizer, Full sun, Seasons, Silvopastoral system.

Received:23/07/2020

Accepted:04/02/2021

Introduction

From the sustainability viewpoint, silvopastoral systems are important for being a valuable tool to assist the recovering of degraded pastures. The pasture degradation process is related to soil physical and chemical deterioration that can be reduced or avoided when trees are introduced to reduce rain impact on the soil and the wind speed in the area, besides helping to sustain and improving soil physical properties(1). Besides, the Brazilian government has undertaken reducing greenhouse gas emissions forecasted for 2020 between 36.1 % and 38.9 %, and to increase the use of degraded pasture recovery technologies and the integration between farming-animal husbandry-forestry, among other commitments(2).

The presence of trees alters the microclimate, reducing solar radiation and temperature and increasing the humidity of the air and soil(1). Thus, according to the authors, the environmental conditions of the soil and its interface with the litter, improve the microbiological activity and the mineralization rate of nutrients. Well-established and managed pastures can contribute to increasing the rate of soil C sequestration(3). In the pastures, the shade provided by the trees provides animal ambience, decreasing thermal stress and improving animal performance(4).

Regarding the sward, shading around 35 % increases the crude protein content, reduces the neutral detergent fiber content, and increases the digestibility of grass growing under the canopy of trees(5). In addition, changes in the amount of chlorophyll occur. Oliveira *et al*(6), observed an increase in the levels of chlorophyll a in shade plants of *Panicum maximum* cv. Tanzania and *Andropogon gayanus* cv. Planaltina, in relation to full sun. The advantages of trees in pasture production, however, depend on the degree of shading, which varies a lot depending on the age, spacing and arrangement of the tree componente(7).

Even though not selected for this purpose, the main forages grown in Brazil can be used in silvopastoral systems(8). The forage response to shading depends on plant tolerance, treetop architecture, and soil fertility, while the positive effect is associated with increased N availability in the soil(1). From the viewpoint of productivity as well as environmental and economic sustainability, successful cattle ranching in pastures requires great attention to soil fertility. Several studies in the literature consider the influence of soil fertilization on the morphological or productive parameters of *Urochloa brizantha* cultivars: nitrogen and/or phosphorus(9-14), and nitrogen and potassium(15). However, there are few specific studies on foliar fertilization in forages.

Forage management requires careful monitoring of important sward structural parameters such as pasture height, forage mass, leaf density, and quantity since they affect forage production and animal the most(16). The stem mass is also of great importance because it affects animal consumption while decreasing the nutritive value of the available forage. Besides the aerial shoot, the root system is responsible for absorbing nutrients from the soil and for accumulating plant organic reserves, which are fundamental to plant recovery after defoliation.

To this end, it becomes clear the importance of silvopastoral systems, as well as knowing forage behavior under shading, and using foliar fertilization as a complementary technique to conventional fertilization. Hence, this work evaluates the structure of a forage sward planted with *Urochloa brizantha* cv. BRS Paiaguas and BRS Piata fertilized via foliar in three different levels and control, under Eucalyptus shading and full sun and during rainy and dry seasons. The results should contribute new information on the use and management of the studied forages in silvopastoral systems.

Material and methods

The study was conducted in Aquidauana, MS (20˚27'S and 55˚40'W, 170 m average altitude). The regional climate is Aw (tropical savannah), according to Köppen(17), and the soil is Ultisol sandy loam texture(18). Two simultaneous experiments were conducted in two areas each, the first under a Eucalyptus shading system and another in full sun (control). The evaluated forages were *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster [syn. *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.] cv. BRS Paiaguas and cv. BRS Piata. Each cultivar was used in one experiment. In 2015, soil samples were collected and sent for chemical analysis. The soil was prepared by applying 3 L/ha glyphosate, followed by harrowing to control matocompetition in the area. The soil chemical analysis indicated the following results: pH in water 5.32; 15.85 g/dm^3 organic matter; 3.96 mg/dm^3 P; 0.15 cmol/dm^3 K; 1.9 cmol/dm^3 Ca; 1.0 cmol/dm^3 Mg; 0.10 cmol/dm^3 Al; 2.68 cmol/dm^3 H + Al; 3.05 cmol/dm^3 base sum, and 53.23% base saturation. Based on these results, limestone was applied followed by harrowing to incorporate the lime into the soil.

In the areas designated for the shading system, subsoiling was performed in the tree planting rows between 30 and 40 cm deep. Before planting at the end of 2015, the Eucalyptus seedlings were treated with mono-ammonium phosphate (1.5%) and imidacloprid based insecticide (0.5%). The tree seedlings were planted in East-West single rows, spaced 14 m between rows and 3 m between trees. The clones I-144 and 1277 of *Eucalyptus grandis* x *Eucalyptus urophylla* hybrids were planted, fertilized with 80 g NPK/plant (06-30-06) and irrigated with approximately 4L water per plant. After 60 d, matocompetition was controlled by manual weeding between trees and mechanical brushing between rows. Subsequently, the Eucalyptus trees were fertilized with 80 g NPK/plant three more times, at 90 and 180 d (20-00-20), and 12 mo (00-00-60). At the end of the experimental period, the eucalyptus trees had an average height of 11.98 m (ranging from 7.92 to 14.97 m) and approximately 2 yr of age.

The cv. BRS Paiaguas and cv. BRS Piata grasses were sown in both areas, in November 2016. The areas were divided into three blocks, with four experimental units per block, totaling 12 experimental units (10 m x 9 m each) for each system (shaded and full sun). Twenty (20) rows of forage were sown per experimental unit, using the recommended amount in grams. The experimental units were irrigated until the plants were able to develop without irrigation and, from then on, the experimental units were submitted to 15cm tall uniformity cuts at the beginning of every season. Also, the 2.4 D herbicide was applied to control the weeds in the rows between the experimental units.

The evaluation period from August 2017 to March 2018 was divided into dry (82 d from August to November 2017) and rainy (88 d from December 2017 to March 2018) seasons. The average temperatures and accumulated rainfalls were 27.2 ºC and 183.6 mm and 26.6 ºC and 673.0 mm in the dry and rainy seasons, respectively.

Besides evaluating the shaded and full sun systems, three levels of foliar fertilization were evaluated, Quimiorgen Pasto® (3, 6 and 9 L/ha) with 2 L/ha Niphokam®, and the control (without foliar fertilization). The Quimiorgen pasto® nutrient percentage and concentration were 20% and 270.0 g/L phosphorus (P_2O_5); 0.5% and 6.75 g/L boron (B); 3% and 40.5 g/L manganese (Mn), and zinc (Zn). Whereas, Niphokam® composition was 10% and 135.0 g/L nitrogen; 8% and 108.0 g/L phosphorus (P_2O_5), and potassium (K_2O); 1% and 13.5 g/L calcium (Ca), and zinc (Zn); 0.5% and 6.75 g/L magnesium (Mg), boron (B), and manganese (Mn); and 0.2% and 2.70 g/L copper (Cu).

The foliar fertilizer was applied using a CO_2 pressurized backpack spray. The total amount applied to each experimental unit was calculated according to the equipment calibration, considering the recommendation of 200 L/ha syrup (the two foliar fertilizers plus water) and the levels recommended in the treatments. Fertilization was conducted in the afternoon to avoid day hottest hours while seeking to maximize humidity so that the fertilizer was better absorbed by the leaves. In all experimental areas, fertilizer was applied at the beginning of each season, one week after the uniformity cut, to ensure enough leaf absorption area.

The evaluated structural parameters were average sward height and total forage mass, as well as leaf, stem, dead material and root mass. Except for root mass, evaluations were performed at 28-d intervals, on 28, 56, and 84 d after foliar fertilization, totaling three evaluations in each season (dry and rainy). In the dry season, foliar fertilization occurred in early August and the three evaluations occurred in early September, October, and November 2017, respectively. In the rainy season, foliar fertilization occurred in early December 2017 and the evaluations in early January, February, and March 2018. Root samples were collected at the end of October 2017 and February 2018, for the dry and rainy seasons, respectively.

The average sward height was measured in 20 random points representing the mean height of each experimental plot, using a cm-graduated ruler. Two forage samples inside a 0.0625 m² area defined by a metal frame were cut close to the soil. Each sample was divided into two subsamples. One subsample was weighed, dried in a forced circulation oven at 65 ºC for 72 h, and weighed again to obtain the total dry matter. The other sub-sample was separated into leaf, stem and dead material morphological fractions, which were weighed, oven-dried at 65 °C for 72 h, and weighed again. The total forage mass and masses of the different morphological components were obtained from the fresh and dry weights.

In each experimental area, root samples were collected at places representing the average sward height, which was determined the day before sampling by measuring the height in 20 random points using a cm-graduated ruler. A 15cm-tall steel cylinder with 15 cm diameter was completely introduced into the soil for sampling the roots and shoot parts. The first part of each sampling consisted of cutting the sample aerial shoot at 5 cm from the ground, followed by the complete introduction of the cylinder into the soil for root and soil removal. These samples were always taken between 6 and 10 h in the morning to avoid the variations of reserve carbohydrate contents[19] and nitrogen compounds[20] that occur throughout the day in the plant accumulation organs.

After removal, the root samples (plus stem basis) were packed in plastic bags and placed in a polystyrene box with ice to avoid losses of soluble compounds and, consequently, mass, and immediately taken to the laboratory. To remove the soil from the roots, each sample was washed in running water over a 3 mm mesh sieve and immediately frozen[21] for subsequent drying. After thawing, the samples were again washed to remove the remaining soil, weighed, dried at 65 °C for 72 h and reweighed. The root mass was determined using the fresh and dry weights.

The experimental design consisted of a randomized block with 3 blocks and 4 plots per block, for each shading system, totaling 12 experimental units per system in each season. The data were analyzed as a 4x2x2 factorial arrangement (four phosphate fertilizer levels x two shading systems x two annual seasons (rainy and dry)), considering the data collected in each plot in each season, as time-repeated measures in the same experimental unit. All interactions were evaluated, and removed from the model when not significant, or adequately unfolded.

The data were analyzed using PROC GLIMMIX of SAS University (SAS Institute Inc, Cary, CA, USA) and, where appropriate, the minimum square means of the shading systems or the seasons were compared by the pdiff of the LSmeans command. When the effect of the fertilization levels was identified, the average fertilization levels were compared to the control (without fertilization) using an adjustment for the Dunnett test in the pdiff option. In this case, the linear-to-quadratic effects of the used fertilizer levels were also evaluated using orthogonal contrasts. A significance level of 5% was adopted for all statistical analyses.

Results

The forage sward height and mass, leaf and root masses of the two cultivars of *Urochloa brizantha* were not significantly ($P \geq 0.05$) affected by the studied foliar fertilizer levels (Table 1). Similarly, the dead material mass of the cv. BRS Paiaguas was not significantly ($P \geq 0.05$) changed by foliar fertilizer levels. However, the dead material mass of the cv. BRS Piata was significantly ($P \leq 0.05$) altered by the interaction between foliar fertilizer level × growing days, which after unfolding, indicated that the average dead material mass was similar ($P \geq 0.05$) among the treatments in each period: 3,937.14 kg DM/ha for the treatment without fertilization and 3,738.75; 3,993.97 and 3,984.56 kg DM/ha for the 3, 6 and 9 L/ha of foliar fertilizer, respectively.

Table 1: Height (cm), forage mass (kg DM/ha), leaf mass (kg DM/ha), dead material mass (kg DM/ha), and root mass (kg DM/ha) of the two cultivars, for the different foliar fertilization levels (Mean±SEM)

	Foliar fertilization levels (L Quimiorgen/ha)			
	0	**3**	**6**	**9**
	cv. BRS Paiaguas			
Height	51.81 ± 1.74	54.62 ± 1.74	54.64 ± 1.74	52.63 ± 1.74
Forage mass	14,585.0 ± 758.95	12,838.0 ± 758.95	13,547.0 ± 758.95	13,278.0 ± 758.95
Leaf mass	4,893.58 ± 315.25	4,728.92 ± 315.25	4,921.72 ± 315.25	4,779.61 ± 315.25
Dead material mass	4,314.33 ± 331.99	3,787.58 ± 331.99	3,812.67 ± 331.99	3,857.00 ± 331.99
Root mass	22,335 ± 3077.19	16,392 ± 3077.19	17,881 ± 3077.19	19,955 ± 3077.19
	cv. BRS Piata			
Height	58.32 ± 1.60	58.13 ± 1.60	55.63 ± 1.60	55.99 ± 1.60
Forage mass	17,662.0 ± 931.13	16,012.0 ± 931.13	17,625.0 ± 931.13	17,496.0 ± 931.13
Leaf mass	6,746.17 ± 348.36	6,220.08 ± 348.36	6,995.42 ± 348.36	6,732.44 ± 348.36
Stem mass	6,978.31 ± 409.71	6,053.64 ± 409.71	6,635.61 ± 409.71	6,778.75 ± 409.71
Root mass	21,813 ± 3473.95	31,738 ± 3473.95	23,146 ± 3473.95	27,481 ± 3473.95

The stem mass of cv. BRS Paiaguas was significantly ($P \leq 0.05$) affected by the foliar fertilizer level × system interaction (Table 2). In the shaded system, the stem mass was lower ($P \leq 0.05$) for 3 and 6 L/ha compared to 9 L/ha and control. In the full sun system, the stem mass was similar ($P \geq 0.05$) for foliar fertilizer levels and control. On the other hand, the stem mass of cv. BRS Piata did not change significantly ($P \geq 0.05$) for the studied foliar fertilizer levels (Table 1).

Table 2: Stem mass (kg DM/ha) of cv. BRS Paiaguas regarding the foliar fertilizer level × system interaction (Mean±SE)

	Foliar fertilization levels (L Quimiorgen/ha)			
	0	**3**	**6**	**9**
Shading system	6818.67 ± 515.85 [a]	4307.72 ± 515.85 [b]	4975.33 ± 515.85 [b]	5138.11 ± 515.85 [b]
Full sun system	3935.28 ± 448.77 [a]	4334.67 ± 448.77 [a]	4649.00 ± 448.77 [a]	4144.44 ± 448.77 [a]

[ab]Means in the same row, followed by different letters, differ by T-test at 5%.

The systems and seasons had a significant effect ($P \leq 0.05$) on the sward height of the cv. BRS Paiaguás, which was significantly greater in the shading compared to the full sun system and in the rainy season compared to the dry season (Table 3). For the cv. BRS Piata, the sward height was significantly ($P \leq 0.05$) affected by the system × season interaction. In both dry and rainy seasons, sward height was greater (*P*≤0.05) in the shaded system.

Table 3: Height (cm) for the cv. BRS Paiaguas regarding systems and seasons and cv. BRS Piata regarding system × season interaction (Mean±SE)

	Shading system	**Full sun system**
cv. BRS Paiaguas	59.13 ± 1.23 [a]	47.72 ± 1.23 [b]
	Dry season	Rainy season
cv. BRS Paiaguas	34.25 ± 1.23 [b]	72.60 ± 1.23 [a]
	cv. BRS Piata	
	Shading system	Full sun system
Dry season	37.87 ± 0.97 [a]	33.64 ± 0.97 [b]
Rainy season	86.27 ± 1.43 [a]	70.28 ± 1.43 [b]

[ab]Means in the same row, followed by different letters, differ by T-test at 5%.

The forage and root masses of the *Urochloa* cultivars were not significantly affected (*P*≥0.05) by the shaded and full sun systems (Table 4). This effect was also not observed (*P*≥0.05) on the leaf mass of cv. BRS Paiaguas. The cv. BRS Piata morphological components were affected (*P*≤0.05) by the different systems, resulting in greater leaf and stem masses (*P*≤0.05) and lower dead material mass (*P*≤0.05) in the shaded system.

Table 4: Means and standard error of the mean of forage mass, leaf mass, dead material mass and root mass of the cv. BRS Paiaguas and cv. BRS Piata and stem mass of the cv. BRS Piata, for the systems (kg DM/ha)

	Shading system	**Full sun system**
	cv. BRS Paiaguas	
Forage mass	13,900.00 ± 536.66	13,223.00 ± 536.66
Leaf mass	5,068.64 ± 222.91	4,593.28 ± 222.91
Dead material mass	3,521.47 ± 234.75 [b]	4,364.32 ± 234.75 [a]
Root mass	2,1174 ± 2,175.90	17,108 ± 2,175.90
	cv. BRS Piata	
Forage mass	17,787.00 ± 658.41	16,611.00 ± 658.41
Leaf mass	7,034.43 ± 246.33 [a]	63,12.63 ± 246.33 [b]
Stem mass	7,429.56 ± 289.71 [a]	5,793.60 ± 289.71 [b]
Dead material mass	3,322.76 ± 287.71 [b]	4,504.44 ± 287.71 [a]
Root mass	30,690 ± 2456.45	21,399 ± 2456.45

[ab]Means in the same row, followed by different letters, differ by T-test at 5%.

The seasons had no significant effect (*P*≥0.05) on the masses of forage, dead material and roots of both cultivars, (Table 5). However, the leaf and stem masses were significantly (*P*≤0.05) higher in rainy season.

Table 5: Mean and standard error of the mean of forage mass, leaf mass, stem mass, dead material mass, and root mass for the cultivars BRS Paiaguas and BRS Piata in the seasons (kg DM/ha)

	Dry season	**Rainy season**
	cv. BRS Paiaguas	
Forage mass	11,249.00 ± 536.7	15,874.00 ± 536.7
Leaf mass	4,018.50 ± 222.91 [b]	5,643.42 ± 222.91 [a]
Stem mass	3,173.93 ± 243.18 [b]	6,401.87 ± 243.18 [a]
Dead material mass	4,056.82 ± 234.75	3,828.97 ± 234.75
Root mass	16,032 ± 2,175.90	22,250 ± 2,175.90
	cv. BRS Piata	
Forage mass	15,330.00 ± 658.41	19,067.00 ± 658.41
Leaf mass	6,327.14 ± 246.33 [b]	7,019.92 ± 246.33 [a]
Stem mass	4,818.93 ± 289.71 [b]	8,404.22 ± 289.71 [a]
Dead material mass	4,184.24 ± 287.71	3,642.97 ± 287.71
Root mass	24,933 ± 2,456.45	27,156 ± 2,456.45

[ab]Means in the same row, followed by different letters, differ by T-test at 5%.

The growing days affected ($P\leq0.05$) significantly the height and mass of sward leaves and stem of both *Urochloa* cultivars, but not ($P\geq0.05$) the forage mass (Table 6). As the experimental period advanced, sward height increased for both studied forages so that the highest leaf and stem masses were ($P\leq0.05$) measured in the last evaluation at 83 growing days. The dead material mass of the cv. BRS Paiaguas was affected ($P\leq0.05$) by the growing days, being higher ($P\leq0.05$) at 29 d and remaining unchanged at 83 d. However, for the cv. BRS Piata, as previously mentioned, after unfolding the interaction foliar fertilizer level × growing days, no significant difference ($P\geq0.05$) was observed throughout the evaluations.

Table 6: Height (cm), forage mass (kg DM/ha), leaf mass (kg DM/ha), and stem mass (kg DM/ha) and dead material mass (kg DM/ha) of the two cultivars, regarding growing days (Mean ± SE)

	Growing days		
	29	**55**	**83**
	cv. BRS Paiaguas		
Height	37.97 ± 1.51 [c]	48.40 ± 1.51 [b]	73.90 ± 1.51 [a]
Forage mass	10,524.00 ± 657.27	10,680.00 ± 657.27	19,481.00 ± 657.27
Leaf mass	3,281.58 ± 273.01 [b]	3,538.67 ± 273.01 [b]	7,672.63 ± 273.01 [a]
Stem mass	2,791.77 ± 297.84 [b]	3,515.81 ± 297.84 [b]	8,056.12 ± 297.84 [a]
Dead material mass	4,450.48 ± 287.51 [a]	3,625.79 ± 287.51 [b]	3,752.42 ± 287.51 [ab]
	cv. BRS Piata		
Height	42.45 ± 1.39 [c]	51.53 ± 1.39 [b]	77.07 ± 1.39 [a]
Forage mass	13,977.00 ± 806.38	12,459.00 ± 806.38	25,160.00 ± 806.38
Leaf mass	5,388.54 ± 301.69 [b]	4,628.52 ± 301.69 [b]	10,004.00 ± 301.69 [a]
Stem mass	4,454.31 ± 354.82 [b]	4,876.69 ± 354.82 [b]	10,504.00 ± 354.82 [a]

[abc]Means in the same row, followed by different letters, differ by T-test at 5%.

Discussion

Most of the evaluated structural characteristics of the cultivars BRS Paiaguas and BRS Piata were not significantly affected ($P \geq 0.05$) by the treatments, indicating that the foliar fertilizer levels used were not enough to interfere with sward development. This result may also be probably attributed to the fact that fertilization was conducted only once at the beginning of each season, allowing to infer that a higher frequency of foliar fertilization can modify this picture.

On the other hand, specifically, the cv. BRS Paiaguas stem mass was affected ($P \leq 0.05$) by the treatment × system interaction, differing only in the pastures under shading. The stem mass was significantly ($P \leq 0.05$) lower for the 3 and 6 L/ha fertilization levels compared to control, allowing to conclude that foliar fertilization up to 6 L/ha applied at the beginning of the seasons can help control stem mass in the cv. BRS Paiaguas sward under shading.

The mass of forage, leaves, and roots of the BRS Paiaguas cultivar was not significantly affected ($P \geq 0.05$) by the studied systems. A similar result was observed for the mass of forage and roots of the cultivar BRS Piata. Additionally, the dead material mass was lower ($P \leq 0.05$) for the two cultivars in the shaded system. Therefore, it can be infer that the evaluated forages are adapted to the shading imposed by the silvicultural design (Eucalyptus planted in East-West single rows, spaced 14 m between rows and 3 m between trees) since the productivity was maintained, with less senescence and death of different plant parts.

Likewise, Soares *et al*[22] worked with *Pinus taeda* in a similar arrangement, 15 m space between rows and 3m between trees, and reported similar dry matter content for *Urochloa brizantha* cv. Marandu cultivated in full sun. These authors found that the production decreased with decreasing light intensity, especially for 9 m spacing between rows and 3 m between trees, correlating this low production with less space between trees, and the quality and quantity of radiation reaching the sward. The photosynthetic radiation was three and six times lower in the 15 and 9 m spacing between rows, respectively, under crown projection than in the full sun.

Urochloa decumbens and *Urochloa ruziziensis* evaluated in full sun and under 36 and 54 % shading, maintained the forage production, but reduced the number of tillers and root mass, with increasing shading[23]. These authors concluded that both forages were shading tolerant but severe shading should be avoided because it reduces tillering and root mass, which may in the long run compromise the persistence of pastures.

This adverse effect of increasing shade on the growth of tropical forages has also been confirmed by other authors. In *Urochloa brizantha* cv. Marandu swards with 50 % and 70 % shading, the DM accumulation rates decreased by 13 % and 60 % compared to full sun, respectively[24]. In *Urochloa decumbens* swards, forage mass, tillering density, and leaf area index decreased for 65 % shading but remained unchanged for 35 % shading compared to full sun[5].

In the BRS Piata pastures, the systems had a significant effect ($P \leq 0.05$) on leaf and stem masses, which were greater ($P \leq 0.05$) in the shaded system than in the full sun. The plants possibly lengthened their leaves to increase leaf area and capture more light, contributing to the increasing leaf mass. Also, when less light enters the sward, the plants lengthen their stems to position the leaves in the higher strata to facilitate capturing the incident light. The stem elongation contributed to the increasing sward height.

Shading changed the *Urochloa decumbens* pasture morphologically since leaf and stem, as well as leaf blades, elongated[25] to increase the interception of the photosynthetic active radiation[5]. These authors worked in a consortium pasture of *Eucalyptus grandis* forest and tree legumes and reported higher leaf elongation rates than in the full sun, indicating alterations in the photoassimilate allocation pattern with a consequent greater leaf area to capture light.

The masses of forage, dead material, and roots of the BRS Paiaguas and Piata forages were not significantly ($P \geq 0.05$) affected by seasons. The results indicate that the *Urochloa* cultivars might be used during the dry season, when water becomes scarce since forage production was maintained, without losses due to senescence and tissue death. Tiller mortality and leaf area reduction due to accelerated senescence of older leaves and higher growth of the root system are a few plant strategies used to limit transpiration surface and aggravating water deficiency[26].

The lack of significant results in the root mass is probably related to the free growth (without cutting or grazing) of pastures during the experimental period. In defoliation absence, the forages did not need to relocate the reserve compounds to promote new growth of the aerial part, not altering, therefore, the root system. Removal of the aerial part stresses the plants to a degree directly correlated with the defoliation intensity[27]. As the aerial part is used, photosynthesis and nutrient uptake by the roots decrease to recover the remaining leaf area, damaging the development of new tillers and, consequently, of the roots[28]. The recovery speed of the aerial shoot and root growth depends on physiological mechanisms such as the use of organic reserves[29].

In both forages, the seasons affected significantly (P≤0.05) masses of the morphological components. Leaf and stem masses were higher (P≤0.05) in the rainy season due to the better growing conditions provided to the plants, especially rainfall. The higher plant development culminated in greater height (P≤0.05) of the forage sward in this season.

Greater elongation of leaves and stems and, consequently, greater masses are expected in climatic conditions that maintain soil moisture, favoring plant development. *Urochloa decumbens* in the silvopastoral system showed lower rates of leaf and stem elongation in winter compared to other seasons, mainly due to water deficit and low temperature[25]. In *Urochloa brizantha* cv. Marandu, leaf elongation, appearance, and final length decreased with reduced irrigation[30].

During the study, the accumulated rainfall was 183.3 mm in the dry season as opposed to the 673.0 mm in the rainy season, indicating that the water quantity affected the most the variation of sward structural characteristics for the two *Urochloa brizantha* cultivars evaluated. The water deficit during the dry season in most of Brazil is responsible for the seasonality of forage production[26]. The author pointed out that water deficiency changes plant anatomy, physiology, and biochemistry, affect plant growth to an extent that depends on the water deficit degree and duration, as well as the plant species.

Taller swards are commonly observed under conditions favorable to the growth of forage plants. In *Urochloa brizantha* cv. Marandu, *Setaria sphacelata* cv. Kazungula and *Panicum maximum* cv. Tanzania pastures that were cut at 35 growing days, greater heights were observed in spring and summer, between December and February[31]. The authors also observed that the variation in pasture heights followed the same behavior observed for dry matter production in the different seasons of the year.

The growing days affected significantly (P≤0.05) the height and mass of leaves and stems of both cultivars, but not (P≥0.05) the forage mass. Leaf and stem masses were higher (P≤0.05) at 83 growing days. These results were expected because the pastures did not undergo defoliation, causing accumulation of non-grazed leaves and stems.

The lack of defoliation can diminish the photosynthetic capacity of the sward and the capture of light. Shortly after defoliation, photosynthesis decreases, especially due to the removal of the younger leaves from upper strata, so that the process becomes more dependent on less photosynthetically active leaves(29). Additionally, the size and activity of the photosynthetic apparatus are directly related to the amount of assimilated light, which becomes available to the dry matter accumulation process of the pastures.

Another point to consider when allowing pasture free growth is the mutual shading between plants. In this situation, the light intercepted by the canopy decreases causing the plants to lengthen their stems to that the leaves are placed higher in the sward strata, to increase light uptake. Consequently, the height of the sward increases. Casagrande *et al*(32) observed stem elongation in *Urochloa brizantha* cv. Marandu, as the forage supply increased, that is, with the reducing defoliation intensity. These authors explained that the greater sward height in the greater forage allowances resulted in the mutual shading of the tillers and intense light competition in the swards, concluding that pastures managed with fodder offerings close to 4% LW/day have lower stem elongation and tend to reduce senescence losses.

Conclusions and implications

Foliar fertilization up to 6 L/ha favors the control of stem mass of cv. BRS Paiaguas under shading. Can be suggest further studies using higher fertilizer application frequency to obtain conclusive results on the impact of foliar fertilizer levels on other structural variables of *Urochloa brizantha* of the BRS Paiaguas and BRS Piata cultivars. Considering the masses of forage, leaves, dead material and roots, it is possible to affirm that the two cultivars are adapted to shading of *Eucalyptus grandis* x *Eucalyptus urophylla* hybrids, planted in East-West single rows, spaced 14 m between rows and 3 m between trees, with an average height of 11.98 m and approximately two years of age. A long-term study is indicated since the height of the trees and, consequently, the level of shading, change over time and may show more significant differences in the results obtained between shaded plants and in full sun. Furthermore, the masses of forage, dead material, stems, and roots indicate that the studied forages tolerate well dry season conditions, especially, the low precipitation.

Acknowledgments

To National Council for Scientific and Technological Development (CNPq, process nº 454622/2014-7) and Foundation for Support to the Development of Education, Science and Technology of the State of Mato Grosso do Sul (FUNDECT, process nº 23/200.256/2014) for the financial support to the project. To Coordination of Improvement of Higher Level Personnel/ National Postdoctoral Program (CAPES/PNPD) for the awarded grant (process nº 88882.317872/2013-01). To Universidade Estadual de Mato Grosso do Sul, in Aquidauana, for offering the necessary conditions and the opportunity to do the work. To Quimifol for providing the foliar fertilizer. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES) – Finance code 001.

Conflict of interest

The authors declare that they have no conflict of interest.

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