

Mixed production of Alexandergrass and sorghum under nitrogen fertilization and grazing intensities

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Abstract

Annual pasture species are used in southern Brazil to supply forage in the fall and spring when major forage species have their productivity diminished. Forage sorghum (*Sorghum bicolor*, (L.) Moench) is a suitable option that has been adopted by farmers due to its high quality as forage. It has been observed that in areas where forage sorghum is cultivated, alexandergrass (*Urochloa plantaginea*) usually appear as a spontaneous species. The aim of this study was to observe the effect of two grazing intensities (30 and 60 cm of sward height) and two nitrogen fertilization levels (0 and 200 kg N ha⁻¹) on the quantity (forage mass), quality (CP, ADF, NDF, Lignin, Hemicellulose, Cellulose) and morphological components (stem, leaves, senesced material) of sorghum-alexandergrass mixed pasture grazed by beef cattle. Treatments were arranged in a completed randomized block design with three replications in a 2 x 2 factorial scheme. Forage mass was increased during the evaluation period. In the first period, production was 4,022 kg and it reached 5,233kg DM ha⁻¹ in the third period. Treatments did not affect AG-sorghum mixed pasture botanical profile or quality. It was observed that Sorghum lowered its contribution from 63.4% in the first evaluation period to 21.5% in the third. In contrast, Alexandregress (AG), contribution increased from 17.9 to 52.7% throughout the evaluation periods. Therefore, the addition of Alexandergrass to a planted sorghum pasture is encouraged because it can extend the grazing period into the fall by prolonging the pasture favorable sward structure and nutritive value.

Keywords: Botanical composition; Structural composition; *Sorghum bicolor*; *Urochloa plantaginea*.

Abbreviations: ADF_acid detergent fiber; AG_Alexandregress; CP_crude protein; DM_dry matter; NDF_neutral detergent fiber.

Introduction

Annual pasture species are used in high-input intensive grazing management systems in southern Brazil. On top of their high forage quality, they supply biomass in the fall and spring when major forage species have their productivity are diminished. Forage production and accumulation is affected by genetic, soil and climate factors (i.e. temperature, photoperiod, water availability and nutrients). Among the macronutrients, nitrogen is highlighted due to its presence on proteins, enzymes, phytochromes, coenzymes, nucleic acids (DNA and RNA), nitrogenous basis as well on chlorophyll and phytohormones. Forage sorghum (*Sorghum bicolor*, (L.) Moench.) is a suitable option that has been adopted by farmers due to its high forage production potential, high nutritive value and drought tolerance. It has been observed that in areas where forage sorghum is cultivated, volunteer Alexandergrass (AG) (*Urochloa plantaginea*) is common, as it is on row crops nearby (mainly corn and soybeans). Alexandergrass is considered and managed similar to a weed, not only on row crops but also on forage

fields. However, its excellent tillering and forage accumulation characteristics (Martins et al., 2000; Restle et al., 2002; Sartor et al., 2011; Costa et al., 2011; Menezes et al., 2014; Mezzalira et al., 2014) suggest that managing volunteer Alexandergrass as a forage species can be a viable alternative. Recent research (Oliveira et al., 2018) supports the practice by generating guidelines for Alexandergrass management through herbicide application. Using volunteer AG on cultivated sorghum fields in integrated crop-livestock systems can be a viable low-cost alternative and it will allow longer pasture period of utilization. Annual grasses has a short cycle of utilization characterized by fast structural changes of high magnitude, while a spontaneous grass like AG has a more longer period of utilization because its growth patterns are different.

Nitrogen fertilization and sward height management influence forage accumulation and nutrient usage efficiency. Due to heterogeneity in grazed swards its structure is changed along time. Sward structure impacts animal movement and

distribution, as well as ingestive behavior and daily intake (Mezzalira et al., 2014; Martini et al., 2017). Nitrogen fertilization also can improve dry matter accumulation rate, forage allowance and crude protein level of AG pasture (Martins et al., 2000). The correct utilization of grazing intensity and pasture management can provide high levels of animal production on sorghum or AG pastures (Restle et al., 2002), both forage species studied separately.

Based on the structure and composition of swards it is possible to infer the nutrient intake of grazing animals. The current study shed a light on the understanding of relationships of these variables. The literature on mixed summer pasture where one of the species is volunteer is also scarce. It is hypothesized that nitrogen fertilization and sward height management will support greater plant structure and botanical components heterogeneity, which in turn, will affect the bromatological composition of the pasture. To the best of our knowledge there is no published literature evaluating both treatments and their possible interactions in sorghum and AG mixed pasture. The objective of the present research was to assess the botanical, chemical and structural composition of Sorghum-Alexandergrass mixed pastures under grazing heights and nitrogen fertilization levels.

Results and Discussion

Forage production

The imposed grazing pressure through the put-and-take method was effective to establish the contrasting canopy heights, where a 43 cm was achieved for the smaller grazing height (30 cm was the target) and 64 cm for the taller height (60 cm was the target) to represent the treatments.

Total area application of nitrogen (200 kg ha⁻¹) had no effect on the morphological parameters of the mixed pasture. Even though, grasses like sorghum are responsive to nitrogen application. It is likely that supplying the high level of soil organic matter at sowing and the 42.4 kg N ha⁻¹ provided adequate nitrogen to the pasture throughout the experimental period compared to control (no nitrogen fertilization). It is emphasized that prior to this experiment, the area was cultivated with pinto beans, a crop that is known to produce post-harvest residue with low C/N ratio and fast decomposition rates, making the residue nitrogen rapidly available to the studied pasture. We hypothesize that the sorghum pasture had its nitrogen demand met during all development stages.

The evaluation period was the factor that affected the major number of variables linked to forage production (Table 1). Forage mass was affected by grazing height and evaluation period. No significant interaction was observed for the three factors (grazing heights, nitrogen fertilization levels, and evaluation period). Under the higher grazing height (60 cm), forage mass was recorded at 4,896 kg DM ha⁻¹ and for the more severe defoliation treatment (30 cm) the forage mass was observed at 4,299 kg DM ha⁻¹. Nevertheless, it is important to note that forage mass was increased (P<0.05) during the evaluation period, whereas it was 4,022 kg during the first

period and reached 5,233 kg DM ha⁻¹ in the third, with total amplitude of 1,211 kg DM ha⁻¹ (Fig. 1). On the other hand, the average canopy height was inversely proportional to evaluation period (59.3, 58.5, 43.1 cm). Note that the lowest height was observed in the third period, when the highest values for forage mass were recorded.

Like observed in this study, Roman et al. (2008) also found lower forage mass during the early stages of pearl millet grazing. The researchers suggested that higher forage mass later in the research period was a consequence of tillering, which resulted in a denser sward. Restle et al. (2002) in a similar study on sorghum, reached 1,389 of kg ha⁻¹ green weight, while in this study we achieved 1,675 kg ha⁻¹ green weight.

Post-grazing tillering is promoted by the increased quantity of solar radiation incidence at the bottom sward strata and the change in its quality (infrared/red light ratio) as pointed out by Robson et al. (1988). On top of providing adequate feed to grazing animals, the high forage mass observed in this study also promoted adequate soil cover, softened the effects of weather variation and animal trampling. AG volunteer presence supported high forage mass levels from the beginning to the end of the study period.

Sorghum plants reached reproductive stage approximately 113 days after sowing, which was accompanied by lower leaf lamina quantity and stem elongation. Therefore, AG preponderance in the sward mass started to be noticed. The reason might be that light reached the topsoil layer and aided seed germination, given that it is a positive photoblastic species and opportunistic for filling empty sward spaces.

Sorghum and AG do not differ considerably in relation to forage accumulation and nutritive value (Restle et al., 2002). In grain production areas, AG is considered a competitive weed. On the other hand, it shows potential as a forage due to its excellent yield levels, nutritive value, prolific seed production habit, and fast growth habit that eliminate other species from the habitat. Its forage potential was already suggested by earlier research (Adami et al., 2010; Sartor et al., 2011) as well as an herbicide management guideline as part of a crop-livestock system (Oliveira et al., 2018).

Botanical and structural components

It was observed that sorghum had its contribution lowered from 63.4 % in the first evaluation period to 21.5 % in the third. Meanwhile, AG increased from 17.9 to 52.7 % throughout the evaluation periods (Table 3). Other species and senesced material did not fluctuate significantly (P<0.05).

The AG increases its presence in the mixed sward while senesced material is kept constant along the grazing season. It demonstrates the good opportunity that the mix cultivation offers. It can supply a nutritive diet that does not change as the season progresses.

Botanical composition changes were associated with structural changes in the sward. In the first evaluation period, sorghum participation was significant in all strata and sorghum leaves occupied the higher sward strata (>30 cm). Mezzalira et al.

Table 1. Significance level for sources of variation (grazing height, nitrogen fertilization rate and evaluation period) and their interaction with dry matter (DM, %), forage mass (kg ha⁻¹), Sorghum (%), Sorghum leaf (%), Sorghum stem (%), Alexandergrass (%), senesced material(%), other species (%), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, cellulose and hemicellulose.

Variables	Hgt	N	Alt*N	Per	Per*Alt	Per*N	Per*N*Alt
Forage Mass	0.0473	ns	ns	0.0082	ns	ns	ns
Sorghum (%)	ns	ns	ns	0.0001	ns	ns	ns
Sorghum leaf (%)	ns	ns	ns	0.0002			
Sorghum stem (%)	0.0002	ns	ns	0.0011	0.0034	ns	ns
Alexandergrass (%)	0.0053	ns	ns	<0.0001	ns	ns	ns
Senesced material (%)	ns	ns	ns	ns	0.0134	ns	ns
Other species (%)	ns	ns	ns	ns	ns	ns	ns
CP (%)	ns	ns	ns	ns	ns	ns	ns
NDF (%)	ns	ns	ns	0.0059	ns	ns	ns
ADF (%)	ns	ns	ns	ns	ns	ns	ns
Lignin (%)	ns	ns	ns	0.0011	ns		ns
Cellulose (%)	ns	ns	ns	ns	ns	ns	ns
Hemicellulose	ns	ns	ns	ns	ns	ns	ns

Hgt: sward height; N: nitrogen fertilization level; Per: evaluation period and ns: non-significant (P>0.05).

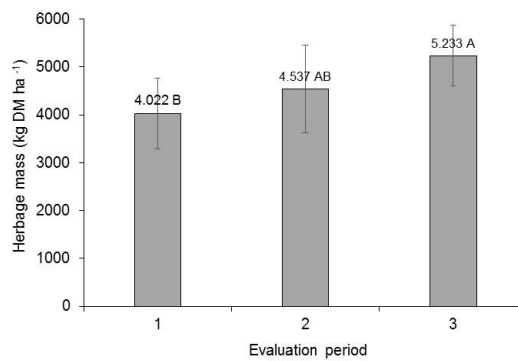


Fig 1. Forage mass (kg ha⁻¹) according to evaluation period (1: February 8 to March 1, 2013; 2: March 1 to March 22, 2013; and 3: March 22 to April 12, 2013). Means followed by the same letter do not differ (P>0.05).

Table 2. Precipitation and climatological normal (mm) during the experimental period, 2013/2014.

Precipitation	Month						
	Oct/12	Nov/12	Dec/12	Jan/13	Feb/13	Mar/13	Apr/13
Climatological normal	163.8	158.2	151.1	142.4	173.4	103.4	106.4
Observed precipitation	257.3	47.4	289.9	133.6	138.3	307.4	181.7

Table 3. Botanical components (Sorghum, Alexandergrass, Senesced material, and other specie) by evaluation period (1: February 8 to March 1, 2013; 2: March 1 to March 22, 2013; and 3: March 22 to April 12, 2013).

	Evaluation Period		
	1 (08-Feb to 01-Mar)	2 (01-Mar to 22-Mar)	3 (22-Mar to 12-Apr)
Sorghum	63.35 A	30.68 B	21.53 B
Alexandergrass	17.91 B	47.80 A	52.73 A
Senesced material	16.68	16.35	19.43
Other specie	2.06	5.16	6.3

Means followed by the same letter within a row do not differ (Tukey's test, P<0.05).

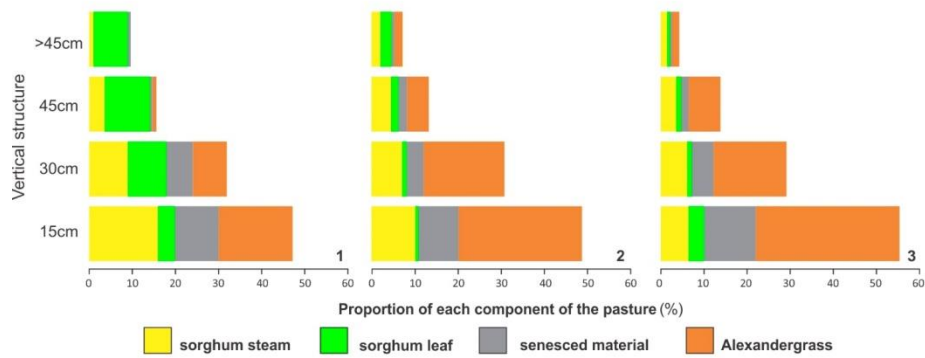


Fig 2. Vertical structure of the pasture (sorghum stem, sorghum leaf, senesced material and Alexandergrass) by evaluation period (1: February 8 to March 1, 2013; 2: March 1 to March 22, 2013; and 3: March 22 to April 12, 2013).

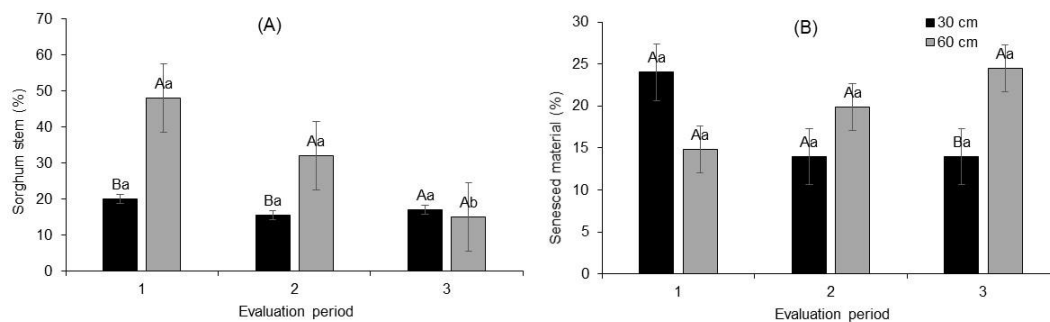


Fig 3. Sorghum stem proportion (A) and senesced material (B) by evaluation periods (EP) and sward heights (H). Means followed by the same capital letter do not differ within EP; means followed by the same lowercase letter do not differ within H (Tukey's test, $P < 0.05$). Evaluation periods were: (1: February 8 to March 1, 2013; 2: March 1 to March 22, 2013; and 3: March 22 to April 12, 2013)

Table 4. Dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, hemicellulose, and cellulose content (%) in hand-plucked samples by evaluation periods

	Evaluation Period		
	1 (February 8 to March 1)	2 (March 1 to March 22)	3 (March 22 to April 12)
DM	16.87 A	15.38 AB	13.58 B
CP	19.07	17.90	17.52
NDF	64.28 A	60.36 AB	57.73 B
ADF	32.15	30.86	30.61
Lignin	5.42 A	5.52 A	3.58 B
Hemicellulose	32.13 A	29.75 AB	26.87 B
Cellulose	26.73	25.09	27.28

Means followed by the same letter within a row do not differ (Tukey's test, $P < 0.05$)

(2014) observed that, in tropical pastures, high intake rates occur when animals graze swards with plenty and reachable (higher sward strata) leaf material. Leaf density for sorghum was the highest in the first period of evaluation (Fig. 2). Nevertheless, with higher swards heights, we observed a lower bulk density in the sward of all components, this information is corroborated by Souza et al. (2011).

Starting on period two, sorghum stem and leaf participation decreased noticeably, increasing the share of AG in the pasture. At the beginning of the study, AG was at the bottom layers (0-15

and 15-30 cm) and the sorghum leaves increased its participation in the overall pasture. The data on Fig. 2 demonstrates that Alexandergrass was the dominant species in the last measurement event.

Changes in sward structures can be elucidated when the evaluation period x grazing height interaction is analyzed (Fig. 3a and 3b). Sorghum stem presence was kept higher ($P < 0.05$) when the sward was managed higher in the first and second period but reduced in the third ($P < 0.05$). Within the lower height treatment (30 cm), stem presence did not differ with evaluation

periods. The significant reduction of canopy height in the third evaluation period was a consequence of senesced sorghum plants and AG prevalence in the sward. This time, there was less senesced material in the 30 cm than in the 60 cm sward ($P < 0.05$). Within the 30 cm, it is possible to notice a trend: senesced material decreased with evaluation periods, whereas the opposite holds true for the 60 cm treatment. AG presence is pointed as the cause for this phenomenon.

Nutritive value

Accumulation of fiber and lowering crude protein contents are consequences of tropical forage growth (Van Soest, 1994). The resultant depressed animal performance is then a consequence of such processes which include new cellular wall growth and thickening (Mertens, 1993). The diminished CP or nitrogen concentration in the sward follows a pattern of attenuation from the top to the bottom layers (Pons and Percy, 1994). Accumulation of structural and storage tissues that are low in N content also contributes to the exposed above (Mertens, 1993). Controversially, in this study, the chemical composition of the pasture was seen constant. CP, ADF and cellulose did not vary with evaluation period nor N-fertilization levels. NDF behaved in an unexpected way, having its lowest values at later evaluation periods. There was also significant reduction in DM, hemicellulose and lignin with time (Table 4).

Supporting previous studies (Souza et al., 2011; Pacheco et al., 2014) suggest that maintaining a nutritive and productive pasture can be achieved through addition of new species that were once perceived and managed as weed in grain production systems. We found that AG served as a complementary species to sorghum pasture because it can extend the grazing period of the mixture.

The growth pattern of the Sorghum plus AG pasture was analogous to the one found by Souza et al. (2011) when looking at grazing behavior of beef heifers in a pearl millet x alexandergrass mixture grazed at 40 cm. The authors found that both species had similar chemical and structural composition, which did not impact ingestive behavior. Several publications point AG as a viable alternative on animal production systems since it keeps its productivity until early Fall when temperature starts to decrease (Martins et al., 2000; Restle et al., 2002; Sartor et al., 2011; Costa et al., 2011; Menezes et al., 2014). Nitrogen fertilization on tropical pastures enhance forage production. However, depending on cut regime it can increase lignin deposition on the cell wall of the plants (Van Soest, 1994). In the second evaluation period, there was higher forage accumulation rate. The increased stocking rate of animals onto paddocks may have enhanced defoliation frequency, keeping younger tissues in the sward. Therefore, no difference in lignin content was observed. In the third evaluation period, when vegetative period of growth of sorghum plants was finished, lignin content was similar, either for sward heights or nitrogen levels. That difference cannot be explained by highest AG high quality forage in the sward.

Volunteer AG grew mainly from the sorghum planting line, and not from the between-lines space ("row space"). As a consequence, when the sward was kept at 30 cm, opportunity was greater for AG to thrive since light reached the soil and

stimulated AG germination from the seedbank. It is emphasized that AG was the main forage in the pasture during the latter periods of the study. It fed animals in April, when the study region is known to go through a forage shortage. Even though the study was finished in April 12, 2013 due to a waning sorghum crop, the remaining pasture would be able to sustain 1,244 kg live weight ha^{-1} .

Extending the forage resource usage period in crop-livestock systems is desirable because it increases the system profitability and maximizes the soil use. It is suggested that until there is no cultivar registration for Alexandergrass by the appropriate department in Brazil (National Register of cultivars of the Ministry of Agriculture, Livestock and Supply), a seedbank should be managed to produce for the following year.

Materials and Methods

Site description

This study was carried out in Abelardo Luz (26°31'S, 51°35'W, 850 m a.s.l.), Santa Catarina, Brazil, from October, 2012 to April, 2013. The climate is Cfb, according to the Köppen classification (Alvares et al., 2014), with well-distributed precipitation throughout the year and mild summers. Climatic data of the experimental period were collected from Meteorological Station at Clevelândia, Paraná (Table 1).

The soil at the study site is classified as Oxisoil and clayey in texture. Soil chemical properties at the beginning of the study were: pH ($CaCl_2$) = 4.57; organic matter = 36.3 g dm^{-3} ; P = 4.57 mg dm^{-3} ; K = 87.87 mg dm^{-3} ; Ca = 3.85 $cmol_{(c)} dm^{-3}$; Mg = 1.97 $cmol_{(c)} dm^{-3}$; base saturation = 55.95%.

Experimental design and treatments

The experiment was performed in a site with a total area of 24 hectares, arranged on a 2 x 2 factorial experiment at randomized complete block design with three replicates (paddocks). The treatments were the combination of two sward grazing heights (30 and 60 cm) and two nitrogen fertilization levels (0 and 200 kg N ha^{-1}) in Sorghum-Alexandergrass mixed pasture, grazed by beef cattle.

Conduction of study

The experimental site was maintained under a crop-livestock system management during previous years. During the winter *Avena strigosa* ("black oat") was sown and grazed. During the summer grain crops corn, soybeans and pinto beans were cultivated. The area was always kept under no-tillage practices. The cover crops in experimental site were desiccated with glyphosate on October 15, 2012 (900 g of active ingredient per ha). Sorghum planting was finished on November 7, 2012, under no-tillage with a multipurpose seed sowing and planting machine. The ADV2800 hybrid was used and a population of 450,000 plants ha^{-1} targeted. The volunteer AG plants (*Urochloa plantaginea*) was obtained from the soil seed bank. During the previous year, in order to guarantee that the seedbank was sufficient, AG pasture was managed at high forage allowance to produce seeds.

Fertilization at sowing followed the guidelines from the Brazilian Commission for Chemical and Soil Fertility (Cqfs/RS-SC, 2004), considering the results from soil analysis conducted just prior to the experiment. A total quantity of 530 kg of NPK fertilizer (08-20-20) was used, which corresponds to 42.4 kg N ha⁻¹, 106 kg P₂O₅ ha⁻¹ and 106 kg of K₂O ha⁻¹.

In order to set the treatments heights, a grazing session was performed on December 20, 2012. The pre-grazing height was approximately 90 cm. After this grazing period, the sward height was standardized in the plots (paddocks) with a mechanical cut at 50 cm above the soil. Afterwards, nitrogen top dressing using 200 kg N ha⁻¹ (urea 45% N) was added and grazers allocated out of the experimental site.

Evaluation period comprised of 65 days, from February 8 to April 12, 2013. Data was collected in three periods (1: February 8 to March 1, 2013; 2: March 1 to March 22, 2013; and 3: March 22 to April 12, 2013).

The put-and-take stocking method was used (Mott and Lucas, 1952) and Nelore by Charolais crossbred steers (319 kg, SE = 34 kg) served as grazing animals. Each experimental unit (plot) had three tester animals and a variable number of animals to assure that sward height targets were reached. Every 21 days animals were fasted for 12 hours and weighed to stocking rate adjustment. The delta between the targeted and the observed sward height dictated the addition or removal of animals from a plot.

Traits measured

The grazing heights were measured in 60 random points on plots every three days, using a meter stick. The observations were recorded to the nearest centimeter. Canopy height was defined as the distance between the top soil layer and the average sward height around the stick.

Forage mass (kg DM ha⁻¹) was estimated every 21 days through three representative samples from each plot. Forage sample delimited by a metal frame (0.25 m²) and were clipped above the ground level (0 cm). The samples were weighed, dried at 55°C in a forced-air oven to constant weight, and weighed again. The evaluation of morphological components in each vertical layer was performed from two samples collected per plot in each evaluation period. Forage samples were cut from the ground level (0 cm) in an area delimited with a metal frame (0.405 m²). For every layer (15 cm), morphological components were manually separated [sorghum leaf lamina, sorghum stem (sheath + stem), senesced material and AG] and dried at 55°C in a forced-air oven to constant weight and weighed. The components were expressed as a proportion of total forage mass (%).

Samples for nutritive value of forage were hand-plucked from each experimental unit according to methodology suggested by Johnson (1978). We replicated the material gathered in a graze bite through a hand-plucked sample by observing the grazing behavior of the animal. Only one observer took the samples in order to avoid person-to-person bias when performing. Grazing simulation was done by walking zigzag in the plot to choose feeding stations, where a sample was taken. One composed sample per plot per evaluation period was used. In the laboratory, samples were dried at 55°C in a forced-air oven for

72 hours and ground. Subsequently, the composite sample was analyzed for crude protein (CP) according to the micro-Kjedahl method (AOAC, 1984), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin according to Van Soest et al. (1991).

Statistical analysis

Data was analyzed using the MIXED procedure of SAS software (version 9.0, SAS Institute Inc.). Evaluation period was used as a repeated measure in time with 5% significance according to the Kenwardroger method (Gutzwiller and Riffel, 2007). Rates were separated based on Tukey's test at 5% significance.

Conclusion

Nitrogen fertilization and grazing height do not affect sorghum x alexandergrass mixed pastures structural components and quality. The addition of alexandergrass to a sorghum pasture can extend the grazing period into the fall keeping favorable sward structure and its nutritive value to livestock production.

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