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Forage yield and nutritive value of hay from sorghum-sudangrass hybrids

Rendimento forrageiro e valor nutritivo do feno de híbridos de sorgo e capim-sudão

Rendimiento de forraje y valor nutritivo del heno de híbridos de sorgo y pasto sudan

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Abstract

The objective was to evaluate agronomically nine sorghum-sudangrass hybrids (*Sorghum bicolor* × *Sorghum sudanense*) and the nutritive value of their respective hays. The experimental design used was randomized blocks in a 3 × 9 factorial scheme, with three replications. Three cuts were made: 42 days after germination, 29 days after regrowth, and 28 days after the second regrowth. All hybrids showed a higher number of plants ha^{-1} ($P < 0.05$) in the second cut. For the green matter and dry matter production of the hays, the values ranged from 49.16 to 62.07 t ha^{-1} and 9.07 to 11.43 t ha^{-1}, respectively. There were no differences ($P > 0.05$) in dry matter, mineral matter, or ether extract. The hybrids 1013020, BRS 810, 1013016, and 1624F016 showed higher values of crude protein (CP) of 16.49, 16.17, 16.08, and 15.88%, respectively. Differences were observed ($P < 0.05$) in neutral detergent fiber (NDF) content. The hybrids 1013020, BRS 802, 1013021, 1013016, BRS 810, and 1624F006 presented lower levels of NDF (60.57, 60.74, 62.15, 62.37, 62.58, and 64.70%, respectively). The hybrids BRS 802, 1013016, BRS 810, and 1624F006, stood out above the others, presenting high forage yield and adequate nutritive value (CP content >13% and NDF content <65%).

Keywords: Cutting and grazing; Genotype; Productivity; *Sorghum bicolor*; *Sorghum sudanense*.

Resumo

Objetivou-se avaliar agronomicamente nove híbridos de sorgo (*Sorghum bicolor* × *Sorghum sudanense*) e o valor nutritivo dos seus respectivos fenos. O delineamento experimental utilizado foi em blocos ao acaso, em esquema fatorial 3 × 9, com 3 repetições. Foram realizados três cortes, com 42 dias após germinação, 29 dias após rebrota, e 28 dias após a segunda rebrota. Todos os híbridos apresentaram maior número de plantas ha^{-1} ($P<0,05$) no segundo corte. Para a produção de matéria verde e seca dos fenos, os valores variaram de 49,16 a 62,07 t ha^{-1} e 9,07 a 11,43 t ha^{-1}, respectivamente. Não houve diferenças (P>0,05) para matéria seca, matéria mineral ou extrato etéreo. Os híbridos 1013020, BRS 810, 1013016 e 1624F016 apresentaram maiores valores de proteína bruta (PB) de 16,49, 16,17, 16,08 e 15,88%, respectivamente. Foram observadas diferenças (P<0,05) no teor de fibra em detergente neutro (FDN). Os híbridos 1013020, BRS 802, 1013021, 1013016, BRS 810 e 1624F006 apresentaram menores níveis de FDN (60,57, 60,74, 62,15, 62,37, 62,58 e 64,70%, respectivamente). Os híbridos BRS 802, 1013016, BRS 810 e 1624F006 se destacaram dos demais, apresentando alta produtividade de forragem e valor nutritivo adequado (teor de PB >13% e teor de FDN <65%).

Palavras-chave: Corte e pastejo; Genótipo; Produtividade; *Sorghum bicolor*; *Sorghum sudanense*.

Resumen

El objetivo fue evaluar agronómicamente nueve híbridos sorgo-sudangrass (*Sorghum bicolor* × *Sorghum sudanense*) y el valor nutritivo de sus respectivos henos. El diseño experimental utilizado fue de bloques al azar en un esquema factorial de 3 × 9, con tres repeticiones. Se realizaron tres cortes: 42 días después de la germinación, 29 días después del rebrote y 28 días después del segundo rebrote. Todos los híbridos mostraron un mayor número de plantas ha^{-1} (P<0,05) en el segundo corte. Para la producción de materia verde y materia seca de los henos, los valores variaron de 49,16 a 62,07 t ha^{-1} y de 9,07 a 11,43 t ha^{-1}, respectivamente. No hubo diferencias (P>0,05) en materia seca, materia mineral o extracto etéreo. Los híbridos 1013020, BRS 810, 1013016 y 1624F016 mostraron valores más altos de proteína cruda (PC) de 16,49, 16,17, 16,08 y 15,88%, respectivamente. Se observaron diferencias (P<0,05) en el contenido de fibra de detergente neutro (FDN). Los híbridos 1013020, BRS 802, 1013021, 1013016, BRS 810 y 1624F006 presentaron niveles más bajos de FDN (60,57, 60,74, 62,15, 62,37, 62,58 y 64,70%, respectivamente). Los híbridos BRS 802, 1013016, BRS 810 y 1624F006, se destacaron sobre los demás, presentando alto rendimiento forrajero y adecuado valor nutritivo (contenido de PC >13% y contenido de FDN <65%).

Palabras clave: Corte y pastoreo; Genótipo; Productividad; *Sorghum bicolor*; *Sorghum sudanense*.

1. Introduction

The production of ruminant animals in regions with a tropical climate is characterized by the use of tropical grasses, this feed source being available predominantly in the form of pastures. However, during the dry season there is a shortage of feed, contributing to the reduction of the productivity of herds and causing financial losses for a livestock activity (Ben Salem, 2010; Hoffmann et al., 2014).

The continuity of milk and meat products based on the availability of supplementary bulky feed, "deferred pasture, hay and silage" of quantity and quality, as the main component of the diets has been a challenge in tropical regions, especially during the dry season. In this sense, feed strategies that aim to minimize production costs and address the lack of bulky strategic feeds (Souza, et al., 2014; Ferreira, et al., 2015; Lima, et al., 2017).

An alternative to rectifying this deficiency in the production of roughage during the dry season is the use of high-quality preserved forages, aiming to provide feed in a quantity and of a quality that meets the nutritional requirements of animals throughout the year and reduces the expenses of supplementation, maintaining the positive profitability of livestock systems (Dos Santos, et al., 2014).

The sorghum crop is a C4 grass belonging to the *Poaceae* family; originating from a tropical climate, it stands out due to its high versatility and economic importance. It presents high biomass production, resistance to salinity and water deficit and grows satisfactorily in soils of medium-to-low fertility. It has several uses and can be used for human and animal feed, ethanol production, and biomass, among others (Getachew, et al., 2016).

The sorghum-sudangrass hybrids arise from the crossing between *Sorghum bicolor* (L.) Moench and *Sorghum sudanense* (Piper) Stapf, also known as cutting and grazing sorghum. These hybrids have been used as an option to supply the demand for roughage and maintain the continuity of forage production (Lima, et al., 2017).

The sorghum-sudangrass hybrids have several characteristics favorable for cultivation and use, such as ease of cultivation, rapid growth and regrowth, high forage yield [30–50 t green matter ha^{-1}; 5–7 t dry matter (DM) ha^{-1}], high nutritive value [100–170 g kg^{-1} crude protein (CP), 560–700 g kg^{-1} neutral detergent fiber (NDF), 40–50 g kg^{-1} lignin, values expressed on a DM basis] and 50–65% *in vitro* dry matter digestibility (IVDMD), standing out as an indispensable forage resource to extend the period of use of fresh or preserved forage with high nutritive value (Tomich, et al., 2006; Gontijo, et al., 2008; Penna, et al., 2010; Ferreira, et al., 2015).

According to May et al. (2011), there is the possibility of haymaking using the sorghum-sudangrass hybrids. Despite being a more laborious process, due to the high amount of water in the stalk that makes it difficult to reduce it to the appropriate humidity level, the process is adapted to the climatic conditions of the semiarid region. To facilitate drying, it is recommended to select more tenuous stalk cultivars for that purpose, using a higher density of plants in the crop, and making the cutting of the plants earlier.

To develop feeding strategies that increase the availability and quality of forage for herds considering the potential use of sorghum-sudangrass hybrids, it is necessary to investigate promising genetic materials and evaluate the agronomic potential of each hybrid and its nutritive value characteristics.

Given the above, the objective this study was to evaluate the agronomic characteristics of nine sorghum-sudangrass hybrids and the nutritive value of hays from these hybrids in successive cuts.

2. Methodology

This work is a field study, with chemical analyzes carried out in the laboratory, the information collected in this study is of a quantitative nature, for discussion of the results, information was collected through search engines previously known on scientific journals indexed in national and international databases. The methodology used in this work was experimental research through the construction of hypotheses and testing of factors and variable responses (Pereira, et al., 2018).

The experiment was carried out in the experimental area of the State University of Southwest Bahia (UESB), in Vitória da Conquista-BA, a municipality located at latitude 15.95º S, longitude 40.88º W, and altitude of 839 m, located in the southwest region of the State of Bahia. The region's climate is classified as high-altitude tropical (Cwa), according to Köppen, with an average annual rainfall of around 733.9 mm.

The soil in the experimental area is classified as a typical dystrophic Yellow Latosol, moderate horizon A, sandy loam texture, and slightly wavy relief (Santos, et al., 2013). Before planting, soil samples were collected in the 0–20-cm depth layer for chemical characterization, which gave the following chemical characteristics: pH (H_2O) 5.6; 1.7 $cmol_c\ dm^{-3}$ of Ca; 0.7 $cmol_c\ dm^{-3}$ of Mg; 0.2 $cmol_c\ dm^{-3}$ of Al; 0.36 $cmol_c\ dm^{-3}$ of K; 35.0 mg dm^{-3} of P (resin) and 53% base saturation.

The soil preparation was carried out conventionally through plowing, harrowing, and opening the planting furrows. The soil analysis and the crop requirement, correction and fertilization were carried out following the recommendations for the use of correctives and fertilizers – 5th Approach, Minas Gerais, Brazil (Ribeiro, et al., 1999).

During the experimental period, there was an accumulated rainfall of 270 mm, the average temperature was 22°C, and the average relative humidity was 85%. In the period September 2 to December 22, 2017, nine genotypes of sorghum-sudangrass hybrids were sown: seven experimental hybrids, 1013020, 1013021, 1013026, 1013029, 1134023, 1134027, 1134029, and 1013016, and two commercial hybrids, BRS 802, and BRS 810. The seeds were provided by Embrapa's National Corn and Sorghum Research Center.

For sowing, 20 kg of N ha^{-1} in the form of urea and 50 kg of P_2O_5 ha^{-1} in the form of simple superphosphate were used. For the covering fertilization, 50 kg of K_2O ha^{-1} in the form of potassium chloride and 120 kg of N ha^{-1} in the form of urea were used, with urea divided and applied three times. Cultural treatments were carried out according to the needs of the crop, and weed control was carried out manually whenever necessary.

Complementary irrigation was used to avoid water stress. The plants were irrigated every 10 days when there was no rain in the region; the soil field capacity (SFC) and the permanent wilt point (PWP) were calculated according to Arruda (1987). The water depth was calculated using the Tank Class A equation: $\sum$ ET0: Evt × Kt × Kc, where Evt = Evaporation in Tank Class A; Kt = Tank Class A Coefficient; and Kc = Crop coefficient. The irrigation data were monitored by the evapotranspiration of the Tank Class A with the help of data provided by the water monitoring system of the UESB.

For all nine hybrids evaluated, three repetitions (blocks) were established, consisting of four rows of 5 m length and 0.5 m spacing between rows, resulting in a total area of 10 m^2. Each hybrid genotype consisted of one treatment, totaling nine treatments, and 35 seeds were used per linear meter. The experimental design used was a complete randomized block, with nine genotypes, three replicates, and three cuts, totaling 81 experimental plots.

The first cut of the plants was carried out at 42 days after germination, the second at 29 days after regrowth, and the third at 28 days after the second regrowth. The cuts were made at the time when more than 50% of the plants had reached the cutting height for the haymaking process (between 0.90 and 1.10 m in height, as recommended by Aguilar, et al., 2015). The two central lines (useful portion) were adopted for the analyses, the two external lines (borders) of the parcels being discarded.

The following parameters were evaluated: number of plants (NP) ha^{-1}, counted at the time of cutting; plant height in m, obtained by measuring the level of the ground at the upper end of the plant in 20% of the plants in each plot; green matter production (GMP), obtained from the weighing of all plants in the useful area of the plot and carried out after cutting 20 cm from the soil; and the dry matter production hay (DMPH), obtained from the hay production and the dry matter content of each hay of the hybrids at the time of cutting.

For the calculation of NP ha^{-1}, GMP ha^{-1}, DMPH ha^{-1} from the samples collected in the two central lines, the correction factor (f) was used (Ferreira, 2008).

f = 10 / (number of lines × line spacing in m × length of lines in m);

NP ha^{-1} = number observed in the two central lines × f × 1000;

GMP t ha^{-1} = production observed in the two central lines (kg) × f × 1000;

DMPH t ha^{-1} = production observed of hay in the two central lines (kg) × f × 1000 × % hay DM.

The sorghum-sudangrass hybrids were harvested manually using a reaper. The harvested material was crushed in a stationary forage machine (Nogueira®, PN-PLUS-2000, São Paulo-Brazil) to a size of approximately 5–10 cm. The material was then put to dry in a covered location, with the material samples being turned every 2 h to standardize the dehydration of the material until reaching the hay point, which was determined through sensory and visual analysis of the material. After drying for approximately three days, the sampled hays were packed in nylon bags in a clean, dry, and ventilated place. Subsequently, the hay samples were stored in plastic bags and identified for further analysis.

The samples were transported immediately to the Animal Nutrition Laboratory of the State University of Southwest Bahia (UESB), Vitória da Conquista-BA and weighed and dried in a forced ventilation oven at 55ºC for 72 h. After drying, the material removed from the oven was left at room temperature for 1 hour to stabilize the weight, afterwards, they were weighed to determine the total dry mass (TDM). The dry samples were ground in a Willey mill, with a 1 mm sieve, and stored for further analysis.

To evaluate the nutritive value, the hays were evaluated for the parameters: DM (Method: INCT-CA G-001/1 and G-003/1), CP (Method: INCT-CA N-001/1), ether extract (EE; Method: INCT-CA G-005/1), mineral matter (MM; Method: INCT-CA M-001/1), cellulose, hemicellulose, and lignin (Method: INCT-CA F-005/1), nitrogen insoluble in neutral detergent (NIND; Method: INCT-CA N-004/1), nitrogen insoluble in acid detergent (NIAD; Method: INCT-CA N-005/1), neutral detergent fiber corrected for ashes and protein (NDFap; Methods: INCT-CA F-001/1) and acid detergent fiber (ADF; Method: INCT-CA F-003/1), according to procedures proposed by Detmann et al. (2012). Hemicellulose was obtained by the difference between the percentage levels of NDF and ADF.

To determine the *in vitro* degradability of DM of each hay used, ANKOM® methodology (Ankom Technology, 2010) was used, adapted to the artificial rumen using the TE-150 incubator (TECNAL®). To calculate the actual or real degradability of the hay of the sorghum-sudangrass hybrids, the formula $p = a + (b \times c) / (c + k)$ was used, where k is the passage rate (2 and 5% h^{-1}; Orskov & McDonald, 1979), a is the water-soluble fraction; B is the potentially degradable fraction; and C is the degradation rate of fraction b (h^{-1}).

The data obtained were subjected to analysis of variance and the means compared using the Scott-Knott test at the level of 5% probability using the ASSISTAT v.7.7 Beta program (Silva & Azevedo, 2016).

3. Results

The results of measurements of height and NP ha^{-1} showed no significant interaction ($P > 0.05$) between the sorghum-sudangrass hybrids and the cuts made.

For the NP ha^{-1}, there was a significant difference ($P<0.05$) between the means of each hybrid; the NP ranged from 309.00 to 457.55 thousand plants ha^{-1} (Table 1).

Table 1. Height and number of plants (NP) of the nine sorghum-sudangrass hybrids, in three successive cuts.

Hybrid	Height (m)				NP (x1000 plants ha^{-1})			
	Cut 1	Cut 2	Cut 3	Average	Cut 1	Cut 2	Cut 3	Average
1013020	0.97	1.09	1.10	1.05a	260.0	405.0	267.0	310.6b
1013021	1.06	1.14	1.08	1.09a	276.0	375.0	276.0	309.0b
BRS 810	0.97	1.01	1.11	1.03a	303.3	405.3	219.3	309.3b
1624F016	1.09	1.11	1.05	1.08a	338.6	508.6	328.0	391.7a
1013029	0.96	1.23	1.15	1.11a	350.6	523.3	481.0	451.6a
1624F006	1.10	0.92	1.10	1.04a	372.6	473.3	347.3	397.7a
1624F005	1.15	1.17	1.00	1.10a	360.6	530.6	425.0	438.7a
1013016	1.10	1.07	1.13	1.10a	358.0	550.6	322.0	410.2a
BRS 802	1.19	1.02	1.02	1.08a	427.3	551.3	394.0	457.5a
Average	1.06A	1.08A	1.08A	1.08	338.5B	480.3A	339.9B	386.3
CV (%)	13.60				18.71			

Means followed by equal lower-case letters in columns and upper case in rows do not differ by the Scott-Knott test ($P>0.05$). CV (%): Coefficient of Variation. Source: Authors.

The hybrids BRS 802, 1013029, 1624F005, 1013016, 1624F006, and 1624F016, had the largest plant populations.

There was no difference (P>0.05) between hybrids within the same cut. However, when comparing the cut averages, there was a difference (P<0.05) of the NP between the three successive cuts evaluated. The second cut NP was higher (P<0.05) than that of the first and third cut.

There was a reduction (P<0.05) in the NP of the hybrids from the second to the third cut (Table 1).

There was a significant interaction (P<0.05) for GMP between the hybrids and the cuts performed (Table 2). There was no significant difference (P>0.05) between the hybrids in the first and third cuts.

Table 2. Green matter production (GMP) of the nine sorghum-sudangrass hybrids. in the three cuts.

	GMP (t ha^{-1})				
Hybrid	Cut 1	Cut 2	Cut 3	Average	Total
1013020	9.83aB	21.33bA	18.00aA	16.38a	49.16
1013021	11.01aB	21.06bA	21.20aA	17.76a	53.27
BRS 810	13.25aB	26.06aA	12.33aB	17.21a	51.64
1624F016	12.44aB	31.33aA	12.86aB	18.88a	56.63
1013029	10.54aB	35.40aA	16.13aB	20.69a	62.07
1624F006	15.32aB	29.26aA	15.13aB	19.97a	59.71
1624F005	18.02aB	28.46aA	13.00aB	19.83a	59.48
1013016	14.13aB	27.13aA	20.67aA	20.64a	61.93
BRS 802	13.80aB	29.10aA	15.33aB	19.41a	58.23
Average	13.15c	27.68a	16.09b	18.97	
CV (%)			25.23		

Means followed by equal lower-case letters in columns and upper case in rows do not differ by the Scott-Knott test (P>0.05). CV (%): Coefficient of Variation. Source: Authors.

In the second cut, there was a significant difference (P<0.05) between the hybrids, with hybrids 1013020 and 1013021 showing the lowest GMP (21.06 and 21.33 t ha^{-1}, respectively). The other hybrids, which showed results superior to the first two, showed GMP values ranging from 26.06 t ha^{-1} for the hybrid BRS 810 to 35.40 t ha^{-1} for the hybrid

1013029.

The GMP in the second cut was higher for all hybrids (P<0.05). When comparing the second cut with the third, only hybrids 1013020, 1013021, and 1013016 were similar, maintaining this increase. The other hybrids showed reductions in GMP in the third cut, similar to those observed in the first (Table 2).

There was a significant interaction (P<0.05) for DMPH between the hybrids and the cuts performed (Table 3).

Table 3. Dry matter production of hay (DMPH) of nine sorghum-sudangrass hybrids in the three cuts.

Hybrid	DMPH (t ha^{-1})				
	Cut 1	Cut 2	Cut 3	Average	Total
1013020	1.81aB	3.94bA	3.32Aa	3.03a	9.07
1013021	2.10aB	3.84bA	3.87aA	3.24a	9.81
BRS 810	2.44aB	4.79aA	2.27aB	3.16a	9.50
1624F016	2.27aB	5.79aA	2.35aB	3.45a	10.41
1013029	1.94aB	6.52aA	2.97aB	3.81a	11.43
1624F006	2.79aB	5.33aA	2.79aB	3.63a	10.91
1624F005	3.34aB	5.28aA	2.41aB	3.68a	11.03
1013016	2.59aB	4.98aA	3.79aA	3.79a	11.36
BRS 802	2.25aB	5.31aA	2.79aB	3.54a	10.35
Average	2.41c	5.08a	2.95b	3.48	
CV (%)			25.22		

Means followed by equal lower-case letters in columns and upper case in rows do not differ by the Scott-Knott test (P>0.05). CV (%): Coefficient of Variation. Source: Authors.

Analyzing the hybrids within each cut, in the first and third cut there was no significant difference (P>0.05) between the hybrids; however, in the second cut, there was a significant difference in DMPH (P<0.05), the hybrids 1013021 and 1013020 presenting the lowest values (3.84 and 3.94 t ha^{-1}, respectively).

Following the same trend as that observed for GMP, the values of DMPH found in the second cut were higher than those found in the first cut for all hybrids (P<0.05) and, when comparing the second cut with the third, only hybrids 1013020, 1013021, and 1013016 were similar to each other, with the DMPH results for the other hybrids of the third cut being lower than those of the hybrids of the second cut and similar to those of the first (P<0.05).

Regarding the DM, MM, and EE contents, there was no difference (P>0.05) between the sorghum-sudangrass hybrids (Table 4). The hays of the hybrids showed DM levels that ranged from 87.60 for the 1624F006 hybrid, to 89.24% for the 1624F006 hybrid, with an average value of 88.32% DM.

For MM, the values ranged from 8.41 for the BRS 802 hybrid to 11.45% for the BRS 810 hybrid, the average MM value of the hybrids being 9.65% (Table 4).

Table 4. Dry matter (DM), mineral matter (MM), crude protein (CP) and ether extract (EE) of the hay of the nine sorghum-sudangrass hybrids.

Hybrid	DM	MM[1]	CP[1]	EE[1]
1013020	88.91a	9.30a	16.49a	2.15a
1013021	87.82a	9.44a	14.31b	1.68a
BRS 810	88.51a	11.45a	16.17a	2.39a
1624F016	88.06a	10.34a	15.88a	2.34a
1013029	88.70a	10.16a	14.48b	2.33a
1624F006	87.60a	9.15a	13.26b	2.50a
1624F005	89.24a	9.40a	13.80b	2.33a
1013016	88.30a	9.25a	16.08a	2.14a
BRS 802	87.80a	8.41a	14.21b	2.27a
Average	88.32	9.65	14.97	2.27
CV (%)	0.74	8.55	7.08	23.09

Means followed by equal lower-case letters in columns and upper case in rows do not differ by the Scott-Knott test (P>0.05). CV (%): Coefficient of Variation; [1]Expressed as a percentage of dry matter. Source: Authors.

For the EE parameter, the values ranged from 1.68 to 2.50%, with an average of 2.27% (Table 4).

Regarding the CP content, a significant difference (P<0.05) was observed between the sorghum-sudangrass hybrids evaluated. The hybrids 1013020, BRS 810, 1013016 and 1624F016 were superior to the others. For the other hybrids, the values were similar, between 13.26 and 14.48% (P>0.05). An average CP-value of 14.97% was observed.

The sorghum-sudangrass hybrids evaluated differed in terms of NDF, hemicellulose and cellulose contents, and were similar (P>0.05) for the ADF and lignin parameters (Table

5).

Table 5. Neutral fiber detergent (NDF), acid detergent fiber (FDA), hemicellulose (HEM), cellulose (CEL) and lignin (LIG) of hay of the nine sorghum-sudangrass hybrids.

Hybrid	NDF	ADF	HEM	CEL	LIG
1013020	60.57b	29.74a	30.83b	26.58c	3.05a
1013021	62.15b	31. 44a	30.70b	27.80b	3.59a
BRS 810	62.58b	32.68a	32.26b	28.13b	4.61a
1624F016	68.21a	31.84a	36.37a	28.40b	3.16a
1013029	70.29a	32.75a	37.54a	28.16b	4.17a
1624F006	64.70b	29.79a	32.46b	26.97c	3.74a
1624F005	67.12a	35.59a	31.52b	32.39a	3.39a
1013016	62.37b	32.64a	29.73b	29.41b	3.63a
BRS 802	60.74b	31.34a	29.40b	28.70b	3.93a
Average	64.30	31.98	32.31	28.51	3.70
CV (%)	5.24	4.10	7.47	2.86	14.23

Means followed by equal lower-case letters in columns and upper case in rows do not differ by the Scott-Knott test (P>0.05). CV (%): Coefficient of Variation. Source: Authors.

For the NDF variable (Table 5), there was a difference (P<0.05) between the hybrids, with higher and similar values (P<0.05) of 67.12; 68.21 and 70.29% NDF for hybrids 1624F005, 1624F016, and 1013029, respectively. The other hybrids, 1013020, BRS 802, 1013021, 1013016, BRS 810, and 1624F006, presented lower levels of NDF (60.57; 60.74; 62.15; 62.37; 62.58; 64.70%, respectively), not differing from each other, the average value obtained being 64.30%.

Regarding the ADF variable, there was no difference (P>0.05) between hybrids. The values ranged from 29.74% for hybrid 1013020 to 35.59% for hybrid 1624F005; the average value obtained was 31.98%.

Regarding the hemicellulose content, a significant difference was observed (P<0.05): higher and similar values were found for hybrids 1013029 and 1624F016 (37.54 and 36.37%, respectively); the other hybrids showed lower values (P<0.05), ranging from 29.40 to 32.46%. The average hemicellulose value found in the present study was 32.31%.

There was a variation between the materials (P<0.05) in terms of cellulose content. The hybrid 1624F005 showed the highest value (32.39%), differing from the others.

Intermediate values were observed for the hybrids 1013021, BRS 810, 1013029, 1624F016, BRS 802, and1013016, which were similar to each other and different from the others. The lowest values (26.58 and 26.97%) were found for hybrids 1013020 and 1624F006 (Table 5).

Regarding lignin, no difference (P>0.05) was observed between the evaluated hybrids. The lignin contents ranged from 3.05 for the genotype 1013020 to 4.16% for the hybrid BRS 810. The average observed value was 3.70% (Table 5).

The NDFap values (Table 6) showed a significant difference (P<0.05) between the hybrids. The hybrids 1013029, 1624F016, 1624F005, 1624F006, and BRS 802 were superior (P<0.05) and similar to each other; the other hybrids showed lower values that ranged from 54.26 to 56.20% NDFap. For this parameter, the average value obtained was 58.15%.

Table 6. Neutral detergent fiber corrected for ash and protein (NDFap), nitrogen insoluble in neutral detergent (NIND), nitrogen insoluble in acid detergent (NIAD) and effective degradability (ED) of dry matter (DM) of the nine hay sorghum-sudangrass hybrids.

Hybrid	NDFap[1]	NIND[1]	NIAD[1]	ED[2] (2%/h)	ED[3] (5%/h)
1013020	54.26b	0.74a	0.17a	53.05a	37.06a
1013021	55.28b	0.87a	0.17a	56.67a	39.91a
BRS 810	55.92b	0.77a	0.22a	54.09a	37.12a
1624F016	61.64a	0.80a	0.22a	50.02a	34.15a
1013029	63.17a	0.85a	0.20a	49.96a	32.90a
1624F006	60.32a	0.48a	0.10b	55.87a	39.48a
1624F005	60.75a	0.74a	0.19a	49.42a	32.91a
1013016	56.20b	0.73a	0.09b	54.31a	37.17a
BRS 802	57.88a	0.57a	0.11b	51.05a	34.63a
Average	58.15	0.73	0.16	52.72	36.15
CV (%)	6.10	19.63	31.29	6.71	8.25

Means followed by equal lower-case letters in columns and upper case in rows do not differ by the Scott-Knott test (P>0.05). CV (%): Coefficient of Variation; [1]Expressed as a percentage of dry matter; [2]Effective pass rate degradation of the 2%/h; [3]Effective pass rate degradation of the 5%/h. Source: Authors.

For the variable NIND, there was no significant difference (P>0.05) between the sorghum-sudangrass hybrids analyzed, the levels ranging from 0.48 for hybrid 1624F006 to 0.87% for the 1013021. The observed average value was 0.73%.

Regarding the NIAD fraction, a significant difference was observed (P<0.05) for the evaluated hybrids, the lowest values were found in hybrids 1013016, 1624F006, and BRS 802 (0.09, 0.10, and 0.11%, respectively); the other hybrids were higher (P<0.05), with values ranging from 0.17 to 0.22%.

For the effective *in vitro* degradability of DM, considering the passage rates of 2 and 5% h^{-1}, no significant difference was observed (P>0.05) for the evaluated hybrids. For the effective degradability at 2% h^{-1} the values ranged from 49.42% for hybrid 1624F005 to 56.67% for hybrid 1013021. An average value of 52.72% was obtained. Regarding the effective degradability at 5% h^{-1} the values ranged from 32.90% for hybrid 1013029 to 39.91% for hybrid 1013021. The average value found was 36.15%.

4. Discussion

The results obtained for the height of the plant were dependent on the standardization of the cut, which was carried out when harvesting the plants when they reached a height close to 1 m. This is the recommended time for hay production, green cutting or grazing for sorghum-sudangrass hybrids. Alternatively, the cut can also be performed at the age of 30–40 days after sowing or the beginning of regrowth; for this reason, as they had been standardized for that, it was not possible to differentiate them.

Plant height is a characteristic generally associated with forage productivity (Aguilar, et al., 2015). When plants are tall, they tend to have higher biomass production, due to the higher percentage of the stalk at the expense of the leaf blade. However, with the advancement of the maturity stage and increase in size there is a reduction in nutritional quality with a loss in the nutritional value of forage and an increase in fibrous fractions. More frequent harvests make it possible to obtain forage of better quality; however, total dry matter production decreases (Perazzo, et al., 2013).

As reported by Von Pinho et al. (2006), the height of the plants has a strong and direct correlation with the DM productivity of grasses. In general, the forage yield of cultivars is related to the size of the plant.

According to Similli et al. (2006), the sorghum-sudangrass hybrids show accelerated growth with marked elongation of the stalk; therefore, it is necessary to pay attention to the height because they can reach up to 2 m in height. However, over time, they produce more stalk than leaves, and this is reflected in an increase in forage production, however of low quality.

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In this work, irrigation was used, mainly in the first month of the experiment due to the absence of rain; this contributed to the satisfactory germination of the hybrids and the establishment of the culture, managing to maintain some similar plants among the hybrids, even when comparing cuts made in periods of high or low precipitation.

The high rainfall, which occurred during the period preceding the second cut in November (112 mm), probably favored the regrowth and tillering capacity of the plants regardless of the hybrid evaluated, and consequently increased the number of plants in the second cut compared to the others.

One of the important characteristics of sorghum-sudangrass hybrids is the great tillering capacity after cutting (Rodrigues, 2000), which leads to a greater number of plants and, consequently, greater biomass production. These results obtained this study contradict with Tomich et al. (2004), who, working with 12 sorghum-sudangrass hybrids, in successive cuts, reported a tendency to reduce the number of plants from the second cut.

The NP ha^{-1} obtained in this work was higher than the values reported by Von Pinho et al. (2006), who evaluated the agronomic characteristics of the genotypes of graniferous, dual-purpose and forage sorghum and obtained values of 167.43, 143.71, and 127.60, respectively, for the cultivars.

In this study, it can be considered that the GMP remained stable during the cuts, since it was low in the first cut, increased in the second and decreased again in the third cut, although, in this last cut, recorded production was still greater than that measured in the first cut. This production stability in successive cuts was also reported by Tomich et al. (2004), unlike in the work carried out by Zago & Ribas (1989). The latter found decreasing yields over successive cuts when evaluating two cut and grazing hybrids grown in the southern region of Brazil.

When cutting at a more advanced stages of plant development, greater DM production is obtained. On the other hand, there is a reduction in the nutritive value of the plant due to the decrease in protein content and digestibility; concomitantly, there is an increase in the content of the fibrous portion (Ribeiro, et al., 2001). In the present study, the cuts were not at an advanced stage of development, and the values obtained for the moment of the cut may be considered adequate.

According to Tomich et al. (2004), the productivity of sorghum-sudangrass hybrids is influenced by a range of factors, the most determinant being genetic variability, soil fertility, water availability, sowing time, development stage of the plant, and the management of the cuts. Due to the great number of factors that act on the productivity of the plants, this makes an adequate comparison difficult between the studies of this type available in the literature.

The average DM values of the hays obtained were within the recommended humidity range in which deterioration of the material is minimal, which is a maximum of 15%. According to Neres & Ames (2015), hay with this DM content can be stored for a long period without risking fermentation, heating, the appearance of filamentous fungi or even spontaneous combustion, so reducing DM losses.

The DM values found in the present study were lower than those found by Athayde et al. (2012) who evaluated the chemical composition of Capim Coastcross (*Cynodon dactylon*) hay at different growth stages and obtained values of 96.65, 96.81, 92.46, and 92.63% DM for the cutting times 20, 40, 60 and 80 days, respectively.

The levels of minerals in plants vary depending on several factors; the type of cultivar being used, the plant's physiological stage, the amount of fertilization carried out in the area, and the genetic differences specific to each species being the most important (Gomide, 1976).

As recommended by the NRC (2001), in most situations the total fat in the diet for ruminants should not exceed 6–7% DM of the total diet, as it can cause a reduction in rumen fermentation, fiber digestibility and the rate of passage. In this study, the EE values can be considered adequate for the type of roughage evaluated, and the values obtained were probably influenced by the early cutting.

Several factors are capable of altering the protein content of sorghum-sudangrass hybrids, including the frequency of harvest, the different spacing and nitrogen fertilization (Penna, et al., 2010).

As reported by Rodrigues (2000), there are no great differences in the nutritional value of cut and grazing sorghum-sudangrass hybrids among the different cultivars available on the market. However, the age of the plant at the time of cutting directly affects the nutritional quality because as the plant advances in its physiological stage, changes in its composition occur, and the CP content of the forage is drastically reduced with a greater accumulation of fiber.

The average CP content (14.97%) found in this study was higher than the average value found by Lima et al. (2017) of 12.98% CP, who also evaluated hay from sorghum-sudangrass hybrids; however, these authors evaluated a greater number of genotypes. All the hays analyzed had adequate CP levels to meet the minimum nitrogen requirements for ruminal flora and for good rumen functioning, which is 7% CP based on the DM of the total diet (Lima, et al., 2017).

In this study, when evaluating the nine sorghum-sudangrass hybrids it is very likely that the genetic variation between them could have caused the differences found in the respective hays. For some hybrids, even though they were harvested early, high NDF values (67.12–70.29%) were observed. In others, lower values of around 60.57% were determined. These differences are probably related to the characteristics of each genotype or to the haying process that could have modified this fraction due to the reduction in non-fibrous carbohydrates during drying, for example.

The NDF contents obtained in this research were lower than the values reported by Pinho et al. (2013) who evaluated the bromatological composition of buffelgrass (*Cenchrus ciliares*) hay and found values of 74.34, 71.82, 75.19, and 77.08% for hays harvested at cutting heights of 30, 40, 50, and 60 cm, respectively. These differences are related to the inherent characteristics of each plant used for the haymaking process, since buffelgrass, before being hay, already has an NDF content 70–75% higher than that of sorghum-sudangrass hybrids.

In the table of Brazilian composition of cattle feed, Valadares Filho et al. (2010) reported an NDF value of 68% sorghum hay, higher than the average value of 64% found in this study.

According to Santos et al. (2011) grasses present different characteristics depending on their stage of development, and these can influence positively or negatively the forage conservation process adopted.

When comparing the average value of hemicellulose of 32.31% to the average value of cellulose of 28.51%, it is observed that the NDF fraction, which is less digestible, is lower than that of greater digestibility; this is interesting since ruminants use the energy present in these components in the form of fatty acids. This conversion occurs through their microbial flora, so the greater the more digestible fraction of the fibrous portion of the food, the greater the amount of fatty acid that may be produced in the rumen (Detmann, et al., 2008).

In this study, among the nine hybrids evaluated two of them were mutants and had a brown vein, which gives them a low amount of lignin in their composition. This characteristic did not cause differences in the lignin content when compared with the other hybrids, as all the hybrids showed reduced values of lignin.

Lignin is highly important in the nutrition of ruminants because it has a negative influence on the digestibility of nutrients; this can be verified through the negative correlations of lignin content with the digestibility of dry matter, cellulose and hemicellulose.

The levels of lignin observed in this research were lower than those reported by Aguiar et al. (2006), who evaluated millet hay cv. IPA-Bulk-1, *S. sudanense* cv. Sudan-4202, Elephant grass cv. Cameroon, Sorghum forage cv. IPA-SF-25 and Sorghum forage cv. IPA-467-4-2, and reported lignin contents of 6.37 cv. IPA-Bulk-1, 4.45 cv. Sudan-4202, 4.52 Elephant grass cv. Cameroon, 5.62 cv. IPA-SF-25, and 5.83% cv. IPA-467-4-2.

According to Tomich et al. (2004), the fractions that refer to ADF and lignin content are more associated with reductions in the digestibility of nutrients, while the NDF content is mainly related to reductions in the animals' voluntary consumption. It can be said that the crushed hay from cut and grazing sorghum evaluated in the present study were more digestible and with greater capacity for consumption by the animals compared to the majority of hays mentioned in the literature.

When the NDF or ADF fractions are determined, insoluble nitrogen is naturally present. This nitrogen associated with the fibrous portion is responsible for characterizing the NIND and NIAD fractions. These two fractions represent an estimate of the damage caused by heat during storage or processing and normal heating, making nitrogen bound to the fibrous fraction of the food unavailable to animals (Silva & Queiroz, 2009).

Among the fractions of forage plants, the NIAD fraction has a high negative correlation with apparent protein digestibility (Weiss, et al. 1999). As reported by Licitra et al. (1996), this protein fraction corresponds to proteins associated with lignin, tannin-protein complexes and products from the Maillard reaction, which have high resistance to microbial enzyme attack and cannot be digested by enzymes present in the animal's gastrointestinal tract.

The average values of NIND and NIAD found in this work were low, which makes the hybrids of interest for use in animal feed, as these fractions are unavailable to rumen microorganisms: when there is a concurrent increase in these fractions, there is a decrease in soluble protein.

The chemical composition can be used as a parameter in determining the quality of the forage plant; however, the composition is dependent on aspects of a genetic and environmental nature and should not be used as the only quality determinant of a forage (Reis, 2005). The composition of the hay has a close relationship with the characteristics of the plant used, and the cutting season, the choice of hay technique and processing are determinants in the quality of the hay (Freixial & Alpendre, 2013).

The similar results found for the effective degradability of the hybrids evaluated in this study are related to the low nutritive variation seen in the sorghum-sudangrass hybrids when harvested at the same cutting height. Rodrigues (2000) observed similar results to those found in this study when evaluating the nutritive value of hay from hybrids.

It is possible the degradability of sorghum-sudangrass hybrids can be changed by the moment of cutting, as cutting in advanced stages of maturity tends to provide lower degradability relative to cuts made earlier, due to the reduction in the protein content and the increase in the fibrous portion (increase in the NDF content; Rodrigues, 2000), which can lead to a decrease in the use of the fiber at the rumen level (Vasconcelos, et al., 2009).

The determination of the degradability parameters of feed for ruminant animals constitutes a relevant factor in animal nutrition, since the degradability of food is directly related to the animal's performance and such information is indispensable in diet formulation systems (Garcez, et al., 2016). Knowing about the degradability of feed makes it possible to include forage in the animals' feed in a way and optimized for the livestock system.

The mean value of effective degradability at a passage rate of 2% h^{-1} (52.72%) in the present study was higher than most values reported by Carvalho et al. (2006), who evaluated hay from elephant grass (*Pennisetum purpureum*), pigeon pea (*Cajanus cajan*) and cassava (*Manihot esculenta*) aerial part. The authors found values of 42.68, 34.74, and 48.26%, respectively, at 2% h^{-1}, being lower only for spineless cactus (*Opuntia ficus-indica* Mill) hay, which showed a value of 71.44%. This becomes important because effective degradability shows how much of the feed is degraded by rumen microorganisms.

The effectively degraded fraction is related to digestion and passage rates. Thus, the determination of the rate and extent of fermentation in the rumen are important parameters in studies of the nutritive value of forages.

5. Final Considerations

All the sorghum-sudangrass hybrids evaluated showed high forage yield for GMP (above 16 t ha^{-1} cut^{-1}) and DMPH (above 3 t ha^{-1} cut^{-1}). The hybrids BRS 802, 1013016, BRS 810, and 1624F006, stood out above the others, presenting high forage yield and adequate nutritive value (CP content >13% and NDF content <65%). Such results indicate the potential of the hybrids evaluated, which can be used as alternatives for the production of forage in cutting regimes for animal feed.

A suggestion for future studies, it would be to carry out experimental tests with the sorghum-sudangrass hybrids that stood out from an agronomic and nutritive value point of view, to assess animal performance when fed with these hybrids.

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