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CHARACTERIZATION OF FORAGE, SWEET AND BIOMASS SORGHUM FOR AGRONOMIC PERFORMANCE AND ENSILABILITY

Abstract – This study evaluated sorghum cultivars' agronomic performance and ensilability with different purpose. The experiment was conducted in Sinop/MT in the 2020 growing season. Eight experimental hybrids from Embrapa (forages 15F30005 and 15F30006, sweet CMSXS 5027, 5030, 5043, and 5045, and biomass 2019B008 and CMSXS 7501), and seven commercial hybrids (forages BRS 658, BRS 659, Volumax, BRS Ponta Negra, the sweet BRS 511, and biomass BRS 716 and AGRI-002E) were planted in a randomized block design, with 15 treatments and three replicates. The highest yields in green matter belonged to the group formed by BRS 716 and CMSXS 5043, with an average of 101.9 Mg ha^{-1}. The group with the highest dry matter productivity was formed by the cultivars AGRI-002E and BRS 716, with a 28.77 Mg ha^{-1} average. BRS 716, AGRI-002E, BRS 658, and 659 showed higher dry matter contents (DM), with 297.7 g kg^{-1} of DM. For buffering capacity, BRS 511 had the lowest value, with 16.2 g kg^{-1} DM. BRS 511 and CMSXS 5030 presented the highest average, 391.7 g kg^{-1} DM for water soluble carbohydrates. All genotypes showed potential to be ensiled and produce silages with a good fermentation pattern.

Keywords: productivity, silage, *Sorghum bicolor.*

CARACTERIZAÇÃO DE SORGO FORRAGEIRO, SACARINO E BIOMASSA QUANTO AO DESEMPENHO AGRONÔMICO E ENSILABILIDADE

Resumo - Objetivou-se avaliar o desempenho agronômico e a ensilabilidade de cultivares de sorgo com diferentes aptidões. O experimento foi conduzido em Sinop/MT, com plantio na Safra 2020. Oito híbridos experimentais da Embrapa (os forrageiros 15F30005 e 15F30006, os sacarinos CMSXS 5027, 5030, 5043 e 5045 e os biomassa 2019B008 e CMSXS 7501) e sete comerciais (os forrageiros BRS 658, BRS 659, Volumax, BRS Ponta Negra, o sacarino BRS 511, e os biomassas BRS 716 e AGRI-002E) foram plantados em delineamento de blocos casualizados, com 15 tratamentos e três repetições. As maiores produtividades em matéria verde foram observadas no grupo formado por BRS 716 e CMSXS 5043, com média de 101,9 Mg ha^{-1}. Para produção em matéria seca (MS), os cultivares AGRI-002E e BRS 716 compuseram o grupo de maior média, com 28,77 Mg ha^{-1}. BRS 716, AGRI-002E, BRS 658 e 659 obtiveram maiores teores de matéria seca, com 297,7 g kg^{-1} de MS. Para capacidade tampão, BRS 511 obteve menor teor, 16,2 g kg^{-1} MS. Para carboidratos solúveis, BRS 511 e CMSXS 5030 apresentaram a maior média, de 391,7 g kg^{-1} MS. Todos os genótipos se mostraram passíveis de serem ensilados e produzirem silagens de adequado padrão fermentativo.

Palavras-chave: produtividade, silagem, *Sorghum bicolor*.

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Brazil has approximately 213.7 million head of cattle, being the country with the largest herd in the world. The country also ranks first in exports, exporting 2.5 million tons of carcass equivalent (TCE). However, it ranks second in meat production, accounting for 10.5 million TCE, behind the US, with 12.3 million TCE (Associação Brasileira das Indústrias Exportadoras de Carne, 2020).

Of the number of cattle heads in Brazil, the state of Mato Grosso stands out with 13.98%. The state has an area of 90.3 million ha, approximately 9.8 million ha destined for crops, and 23.1 million ha for pastures, extensive or intensive. In addition, there are also areas of crop-livestock integration, which add up to 891.7 thousand ha (IBGE, 2017).

According to the Brazilian Beef Exporters Association (Associação Brasileira das Indústrias Exportadoras de Carne, 2020), 8.51% of the country's total area, which represents 72.5 million hectares (ha), is occupied by crops. However, there are 82 million hectares with agricultural potential outside the Amazon Biome, corresponding to 9.63% of the land area.

Despite the extensive arable area, some regions of the country go through periods of climatic seasonality, with low silage availability and, consequently, decreased food quality. Consequently, it reduces animal performance since most national bovine herd grows in extensive systems, thus, having pasture as the primary food. Thus, silage production emerges as an alternative to minimize this impact and make the production and use of silage independent (Stella et al., 2016).

The ensiling process consists of creating a fully anaerobic environment, favoring the growth of lactic acid bacteria (LAB). LAB are responsible for fermenting soluble carbohydrates, mainly glucose and fructose, giving rise to organic acids, especially lactate. The acid generated reduces the pH of the medium, which prevents the multiplication of undesirable microorganisms. This process is divided into four phases: aerobic, active fermentation, stable, and discharge (McDonald, 1981; Kung Jr., 1998).

Among silage plants, corn (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.) Moench) are the most used crops for silage production (Souza, 2008). The majority of sorghum genotypes are sensitive to photoperiod (short-day plants) and have greater tolerance than other cereals. They can also adapt to low fertility soils with the presence of aluminum and respond better to fertilization and water availability than maize (Magalhães et al., 2008; Rodrigues et al., 2015).

Five types of Sorghum cultivated in Brazil are classified according to their purposes and agronomic characteristics: grain, biomass, sugar, silage (silage/cutting and grazing), and broom (Rodrigues et al., 2015). Thus, the choice of genotype for silage is based on the purpose it was developed for and its agronomic characteristics, taking into account the behavior of cultivars such as high silage production, a higher proportion of leaves, stay-green, high productivity of grain, digestibility, resistance to pests, diseases, lodging,

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and its adequacy to mechanized management (Rodrigues et al., 2015).

This work aimed to evaluate the agronomic performance of 15 sorghum genotypes for different purposes and, to attest to their ensilability, to identify experimental genotypes with market potential and suitable to recommend for silage production with good fermentation pattern.

MATERIAL and METHODS

Location and experimental conduction

The experiment was performed between November 2019 and April 2020 in the experimental area of Embrapa Agrossilvipastoril, located in the municipality of Sinop, Mato Grosso, coordinates 11º51'30.0''S, 55º36'25.0''W, and an average altitude of 384 m.

The experimental area, located in the Amazon Biome, has soil classified, according to Santos et al. (2013), as a typical Dystrophic Red Yellow Latosol, moderate A, very clayey texture, and flat relief (Viana et al., 2015). The climate, according to the Köppen climate classification, is Am (tropical monsoon), with an average annual air temperature of 25ºC, an average minimum of 18ºC to a maximum of 33ºC, average annual relative humidity of 83 %, and average annual accumulated precipitation of 2,250 mm (Alvares et al., 2013).

During the experiment period, the accumulated rainfall data were collected in an automatic station of the Embrapa Agrossilvipastoril (Figure 1).

The experimental area was prepared, and 20 days before sowing, pre-planting desiccation was carried out with the herbicides Aurora® and Round Up®, as indicated by the manufacturer. The cultural treatments consisted of applying 340 kg ha^{-1} of NPK 08-28-16 fertilizers during the planting time.

Sowing was carried out on 11/20/2019, with a number of seeds that allowed an average population of 103,140 plants ha^{-1}. The useful plots consisted of two rows of five meters and a spacing of 0.70 m, totaling 7 m^2, and received two topdressing fertilization, one carried out 23 days after sowing, with 250 kg ha^{-1} of the formulated fertilizer NPK 20-00-20 and 44 days after planting, with 200 kg ha^{-1} of the same fertilizer.

A post-emergence herbicide application with 2 kg ha^{-1} of the active ingredient (a.i.) atrazine was carried out to control weeds, and an application of 360 g of a.i. ha^{-1} of chlorpyrifos-based insecticide to control fall armyworm (*Spodoptera frugiperda*).

Genotypes and traits evaluated

Fifteen sorghum genotypes consisting of commercial hybrids from different companies and experimental materials developed by Embrapa Milho e Sorgo, with different use purposes, were evaluated: BRS 658, BRS 659, Volumax, BRS Ponta Negra, 15F30005 and 15F30006, classified as forage, BRS 511, CMSXS 5027, CMSXS 5030, CMSXS 5043 and CMSXS 5045,

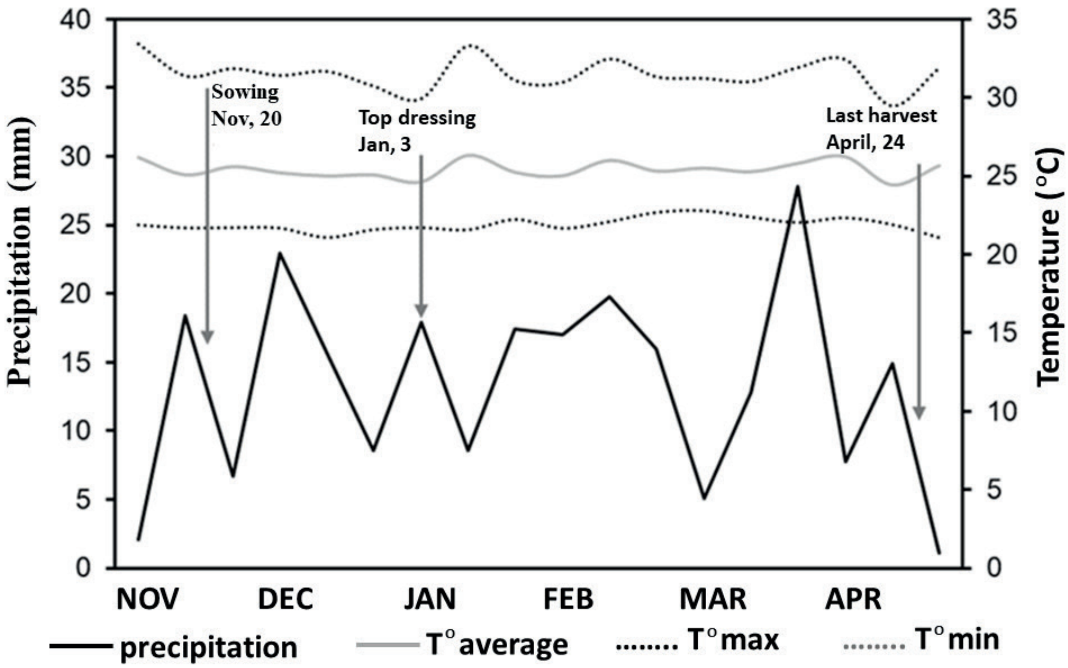

Figure 1. Precipitation rates, minimum, average, and maximum temperature during the experiment conducted in Sinop/MT. Source: Embrapa Agrossilvipastoril meteorological station (2020).

classified as sweet, and the biomasses BRS 716, AGRI-002E, 2019B008, and CMSXS 7501.

Harvest dates varied according to each type of Sorghum, with approximately 101 days after planting (DAP) for forage cultivars, 113 DAP for earlier cycle sweet materials, 140 DAP for dry stalk, and long cycle sweet (biomass pattern), and 156 DAP for biomass (Table 1).

The plants were cut manually at the height of 20 cm above the soil surface, at the point considered ideal for the silage, when the grains of the middle part of the panicle are in the milky/pasty stage (soft dough stage).

The materials were analyzed considering their agronomic performance, collecting data on plant stand, flowering, height, green mass productivity, dry matter productivity and proportion of morphological components (panicle, leaves, and stem) in plant dry matter. In addition, the content of the total soluble solids was measured for verification, aiming for further studies.

The ensilability was evaluated in terms of dry matter content at the time of cutting, the buffering capacity, amount of water soluble carbohydrates, and fermentation coefficient. In addition, the chemical characterization of the forage was also performed.

The total number of plants/tillers per plot was counted at the time of harvest to determine

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Table 1. Planting time, harvest, cycle duration measured for silage, total soluble solids content (in °Brix) at harvest time, and photoperiod sensitivity of the fifteen sorghum genotypes evaluated in Sinop/MT.

Purpose	Genotype	Planting	Harvest	Cycle (days)	TSS* (°Brix)
FORAGE	BRS 658	11/20/2019	02/29/2020	101	4.5
	BRS 659	11/20/2019	02/29/2020	101	6.8
	Volumax	11/20/2019	02/29/2020	101	9.3
	BRS Ponta Negra	11/20/2019	03/02/2020	103	6.0
	15F30005	11/20/2019	03/02/2020	103	6.0
	15F30006	11/20/2019	03/02/2020	103	5.2
SWEET	BRS 511	11/20/2019	03/12/2020	113	14.8
	CMSXS 5027	11/20/2019	03/12/2020	113	12.1
	CMSXS 5030	11/20/2019	03/12/2020	113	12.5
	CMSXS 5043	11/20/2019	04/08/2020	140	13.5
	CMSXS 5045	11/20/2019	04/08/2020	140	15.8
BIOMASS	AGRI002-E	11/20/2019	04/24/2020	156	9.8
	BRS 716	11/20/2019	04/24/2020	156	10.8
	CMSXS 7501	11/20/2019	04/24/2020	156	8.4
	2019B008	11/20/2019	04/08/2020	140	--**

*TSS= Total soluble solids. ** Data not collected.

the stand, and later, the value for plants/hectare was estimated. Flowering consisted of days after planting until 50% of the plants in the plot had the inflorescences of the upper third of the panicle releasing pollen.

The plant height was obtained in meters, considering the average height of three plants per plot, measured from the soil surface to the apex of the panicle, and for green matter productivity, the total plant mass of the usable area of the plot (kg) was obtained, cut at 20 cm from the soil surface, and later estimated in Mg ha^{-1}.

The soluble solids content for materials at the time of cutting, measured in °Brix, was measured with an electric device to read the juice and the reading of an Atago® digital

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refractometer, repeating the reading of each material and making it an average between the values found. The reading was performed for all traits, except for biomass cultivation, collected only for observation without performing statistical analyses (Table 1).

The stem, panicle, and leaves samples were obtained after fractionating three plants per plot. Before and after drying in a forced ventilation oven, each sample was weighed to evaluate its contribution to the total dry matter. The dry matter content and productivity were determined after two drying steps, as Detmann et al. (2012) described.

The methods INCT-CA N-001/1 and INCT-CA N-002/1, proposed by Detmann et al. (2012), were used to determine crude protein (CP) and non-protein nitrogen fraction.

For neutral detergent fiber (NDF) and acid detergent fiber (ADF), the methods INCT-CA F-001/1 and INCT-CA F-003/1 were used. In addition, it was necessary to analyze the neutral detergent insoluble protein (NDIP), by INCT-CA N-004/1 and acid detergent-insoluble protein (ADIP), by INCT-CA N-005/1. For the correction of ash insoluble in neutral detergent (NDIA), and ash insoluble in acid detergent (ADIA), the methods INCT-CA M-002/1 and INCT-CA M-003/1, respectively, proposed by Detmann et al. (2012) were used. After, the neutral detergent fiber and acid detergent fiber (NDFap and ADFap) was estimated.

The sequential method was chosen for lignin after extraction of NDF and ADF, according to “Method 9 – Determination of lignin in acid detergent in the DaisyII incubator (Ankom).” The indigestible neutral detergent insoluble fiber (NDFi) analysis was performed according to the INCT-CA F-009/1 method.

The non-fibrous carbohydrate (NFC) content was calculated based on the values obtained by chemical analysis using the formula “number 10”, proposed by Detmann et al. (2012).

The buffering capacity analysis was performed by the methodology described by Weissbach et al. (1974). The analysis of water soluble carbohydrates (WSC) was according to the methodology proposed by Silva and Queiroz (2002). With pre- dried forage samples, DM, WSC, and buffering capacity defined, the fermentation coefficient was determined according to Weissbach (1996).

After concluding the other analyses, it was possible to perform the calculations referring to each cultivar’s total digestible nutrients (TDN) using the model proposed in the National Research Council (2001).

Statistical analysis

The experimental design used was randomized complete block (RCBD), with 15 treatments (genotypes) and three replicates. The data were submitted for analysis of variance, and the means were compared by the Scott-Knott test, adopting the probability level of 5%, using the statistical application genes (Cruz, 2013). The model used was:

$$Y_{ij} = \mu + T_i + B_j + e_{ij}$$

Being:

Y_{ij}= value of the experimental unit that received treatment i in block j;

μ = general average effect;

T_i = genotype fixed effect i, with i = 1, 2, 3, ... and 15;

B_j = block effect j, with j = 1, 2, and 3;

e_{ij}= experimental error associated with observation.

RESULTS AND DISCUSSION

All measured traits showed significant differences for the genotype source of variation, demonstrating the existence of genetic variability between materials ($p<0.05$).

Nine groups of averages were formed (Figure 2) regarding flowering ($p<0.01$), and the cultivar CMSXS 7501 was the latest (136 days). For cultivars sensitive to photoperiods, such as those belonging to the sorghum biomass group, flowering occurs only after the inductive photoperiod of 12 hours and 20 minutes (Parrella et al., 2010). Under local conditions (southern hemisphere), floral induction occurs from March 21 and extends until September. Although it is still experimental, its flowering is close to the commercial materials of this category, which are BRS 716 and AGRI-002E, with 132 and 133 days, respectively.

Contrastingly, the materials BRS 659 (70 days) and BRS 511 (69 days) were the earliest. Therefore, the cultivars, with forage and sweet purposes, agree with the data from Costa (2017), which found a similar value for BRS 659 (69 days), and Anjos et al. (2019), with 78 days for BRS 511.

For the average height of plants (Figure 3), seven groups were formed ($p<0.01$). The 2019B008, BRS 716, and AGRI-002E materials were taller, with 5.35, 5.26, and 5.20 meters, respectively, and the shorter BRS 658 and 659, with 2.71 and 2.68 m.

The proportion of leaf, stem, and panicle components varied considerably (Table 2). For leaf percentage, five groups were formed ($p<0.01$), being the cultivar Volumax with the highest proportion (202.1 g kg^{-1} DM). Contrasting, the material BRS 716 had the lowest percentage (92.9 g kg^{-1} DM). This fraction may be related to the long cycle and large size. Thus, due to the intense shading, the leaves in the lowest part of the plant lose their photosynthetic function, enter into senescence and dry up, leaving the plant with a reduced amount of green leaves, while the green leaves are concentrated in the higher parts of the plants exposed to light.

Regarding the proportion of stem, four groups of means were formed ($p<0.01$), with BRS 511, CMSXS 5043, CMSXS 5045, AGRI-002E, BRS 716, CMSXS 7501, and 2019B008 making up the largest group, with an average of 797.9 g kg^{-1} DM, close to that found by Rosa et al. (2019) for BRS 716 (795.0 g kg^{-1} DM).

For the proportion of panicles (Table 2),

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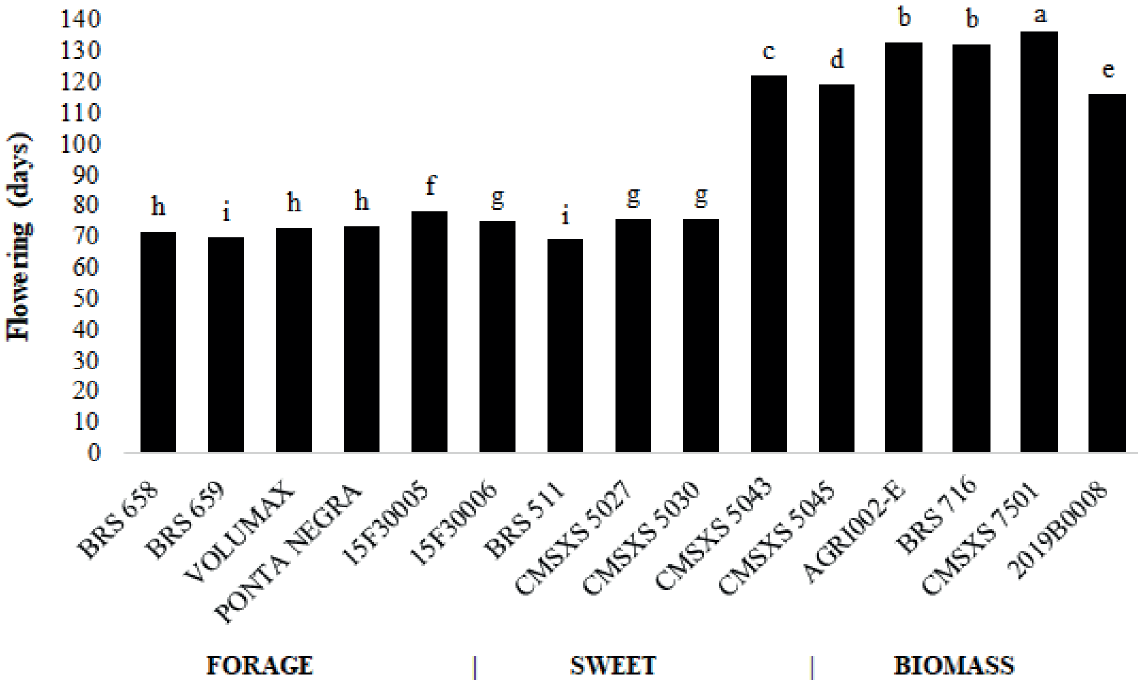

Figure 2. The flowering of the genotypes evaluated in the first crop in Sinop/MT. The flowering was measured in days, and by the Scott-Knott test, means followed by the same letter represent a statistically homogeneous group at 5% probability.

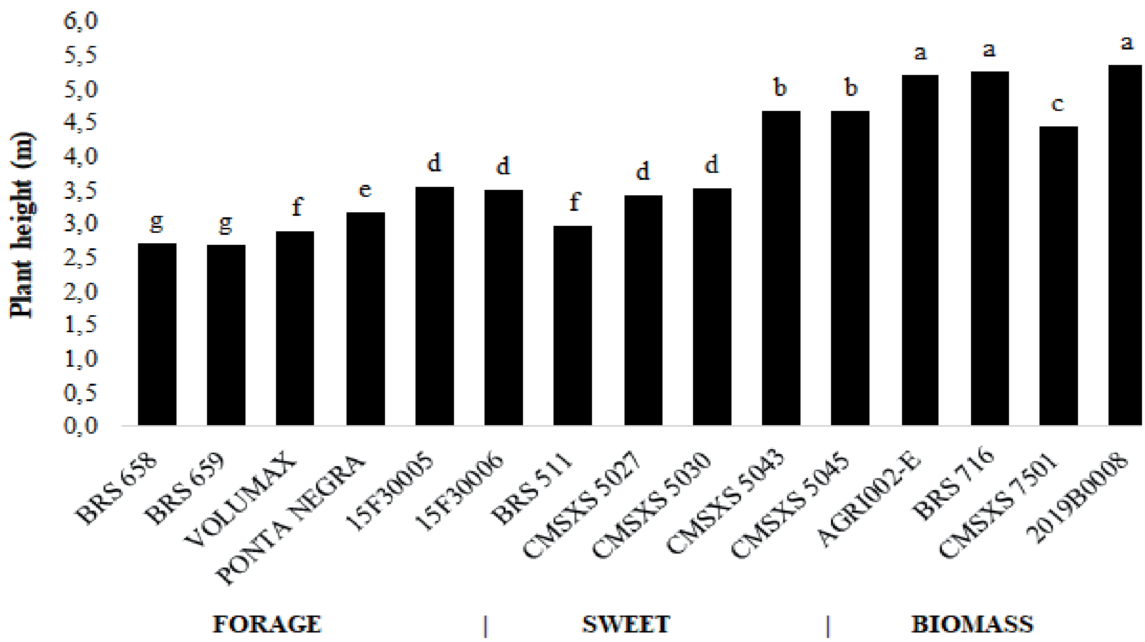

Figure 3. Average plant height, in meters, of the 15 genotypes evaluated in the first crop in Sinop/MT. By the Scott-Knott test, means followed by the same letter represent a statistically homogeneous group at 5% probability.

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Table 2. The proportion morphological components (panicle, leaves, and stem) in plant dry matter of 15 sorghum genotypes evaluated in the first harvest in Sinop/MT.

Purpose	Genotypes	Leaf	Stem ($g\ kg^{-1}$ DM)	Panicle	Dry matter production ($Mg\ ha^{-1}$)
FORAGE	BRS 658	135.6 c	477.0 d	387.4 a	12.64 d
	BRS 659	142.7 c	449.2 d	408.2 a	13.15 d
	Volumax	202.1 a	593.2 c	204.7 c	11.71 d
	BRS Ponta Negra	161.4 b	610.9 c	227.8 c	16.54 c
	15F30005	138.8 c	525.1 d	336.1 b	21.79 b
	15F30006	130.0 c	560.7 c	309.2 b	15.81 c
SWEET	BRS 511	130.3 c	801.5 a	68.2 d	10.26 d
	CMSXS 5027	123.9 c	659.4 b	216.6 c	18.35 c
	CMSXS 5030	131.8 c	666.0 b	202.2 c	17.76 c
	CMSXS 5043	145.9 c	785.4 a	68.7 d	24.53 b
	CMSXS 5045	136.7 c	802.3 a	61.0 d	20.97 b
BIOMASS	AGRI-002E	130.4 c	792.4 a	77.2 d	27.94 a
	BRS 716	92.9 e	803.7 a	103.4 d	29.60 a
	CMSXS 7501	116.3 d	821.7 a	62.0 d	20.10 b
	2019B008	128.4 c	778.6 a	93.0 d	21.57 b
	F	<0.01	<0.01	<0.01	<0.01
	CV (%)	8.43	5.73	20.44	10.54

* By the Scott-Knott test, means followed by the same letter in the column constitute a statistically homogeneous group at 5% probability.

four groups were also verified ($p<0.01$), In this group, BRS 658 and BRS 659 had the highest percentage (397.8 $g\ kg^{-1}$ DM), a value close to that found by Ott et al. (2018) for BRS 655 (423.0 $g\ kg^{-1}$ DM), a material similar in size and characteristics to these two cultivars.

The lowest proportion of panicles group comprises BRS 511, CMSXS 5043, CMSXS 5045, AGRI-002E, BRS 716, CMSXS 7501, and 2019B008 with an average of 76.2 $g\ kg^{-1}$ DM.

Sorghum grain is a starchy cereal, and its nutritional value is similar to that of corn. However, in terms of energy, the sorghum

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grain corresponds to approximately 90% of the energy value of corn and has approximately 78 g kg^{-1} DM of total digestible nutrients (TDN) (Rodrigues et al., 2015). Therefore, when the objective is to use them for animal feed, higher proportions of panicle bring more grains to the ensiled mass, improving the nutritional value of the feed provided.

When analyzing the green matter productivity (GMP) or natural matter, it was observed the formation of three groups (p<0.01), where BRS 716 and CMSXS 5043 had the highest average (101.9 Mg ha^{-1}). This value is similar to that found for BRS 716 by Figueiredo Júnior et al. (2019), of 128.38 Mg ha^{-1} and Almeida (2019) of 98.41 Mg ha^{-1} (Figure 4).

The smallest FMP group was formed by BRS 511, 15F30006, Volumax, BRS 658, and BRS 659, with an average of 49.55 Mg ha^{-1}, a value that can be attributed to the fact that most genotypes have forage purpose, lower cycles than other genotypes evaluated here and, consequently, characterized as minor.

According to data from the Agricultural Census carried out by the IBGE (2017), the green matter productivity of forage maize in Mato Grosso is 18 Mg ha^{-1} on average, while forage sorghum is 26 Mg ha^{-1}. However, the values found in this work are higher than these averages, demonstrating that the use of sorghum of different aptitudes for animal feed is feasible.

As for dry matter productivity (DMP), four groups were formed (P<0.01), with the cultivars AGRI-002E and BRS 716 with the highest average, 28.7 Mg ha^{-1} (Figure 4). This value is close to Venturini (2019), which found 27.33 Mg ha^{-1} for AGRI-002E, and Caxito (2017), 28.29 Mg ha^{-1} for BRS 716.

The group with the lowest DMP, composed of BRS 511, Volumax, BRS 658, and BRS 659, had an average of 11.95 Mg ha^{-1}. Freitas et al. (2020) verified similar results for BRS 658 and Volumax, with an average of 12.89 Mg ha^{-1}. Ott et al. (2018) also found a similar of 12.40 Mg ha^{-1} for Volumax.

The production of dry matter ha^{-1} is significant because cultivars with higher productivity provide a lower cost per kg of DM produced, allow feeding a more significant number of animals using the same amount of cultivation area, and provide a possible reduction in the final production costs. It is also important to emphasize that the production of total dry matter depends on the plant humidity at the time of cutting.

When we use commercial forage materials developed to produce the silages BRS 658, BRS 659, and Volumax forages as comparisons, it was observed that the biomass materials BRS 716 and AGRI-002E reached PMV 113.54% higher than the forages. In contrast, the sweet materials standard biomass (CMSXS 5045, CMSXS 5043, CMSXS 5030, and CMSXS 5027) produced 99.11% more, and the new forage hybrids (15F30005 and 15F30006) produced 57.63% more green.

For DMP, biomass sorghum (BRS 716 and AGRI-002E) were more productive

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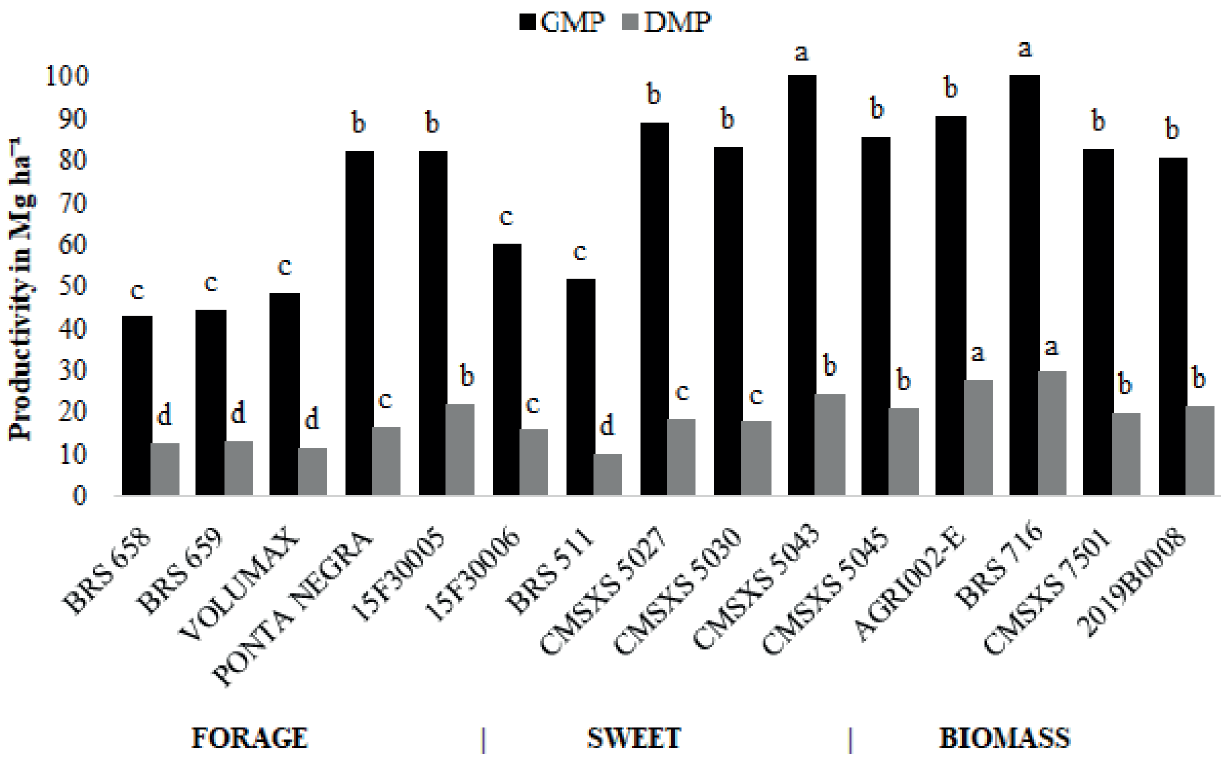

Figure 4. Total green matter productivity (GMP) and total dry matter productivity (DMP) of the 15 sorghum genotypes evaluated in Sinop/MT. By the Scott-Knott test, means followed by the same letter in the column constitute a statistically homogeneous group at 5% probability.

than commercial forage by 130.1%, while the standard biomass sweet increased by 63.19%, and the experimental forage hybrids had higher productivity by 50.35% compared to forage productivity intended for forage. Emphasis must be given to the experimental silage hybrid 15F30005 with PMS of 21.79 Mg ha^{-1}, the only one of this type of sorghum in the second group with the highest averages cultivation cycle of 103 days from planting to harvesting for silage. Other genotypes present in the first and second groups with the highest averages for PMS had cycles longer than 140 days.

For dry matter content at the time of cutting (Table 3), four groups of means were formed (P<0.01).The materials BRS 716, AGRI-002E, BRS 658, and BRS 659 obtained the highest contents, with an average value of 297.7 g kg^{-1} DM. Despite different aptitudes (biomass and forage), the DM content can vary regardless of the type of material. Costa (2017) obtained similar results for BRS 658 and BRS 659, with 239.5 g kg^{-1} DM and 263.0 g kg^{-1} DM, respectively.

The cultivars BRS Ponta Negra, BRS 511, CMSXS 5027, and CMSXS 5030 presented the lowest average, with 204.7 g kg^{-1} of DM.

Table 3. Variables related to biomass ensilability of the 15 sorghum genotypes cultivated in the 2020 harvest in Sinop/MT.

Aptitude	Genotype	variables[1/]			
		DM	BC	WSC	FC
FORAGE	BRS 658	296.1 a	35.8 b	174.7 c	72.89 c
	BRS 659	296.7 a	29.1 c	205.8 c	86.35 c
	Volumax	242.3 c	34.3 b	181.9 c	67.01 c
	BRS Ponta Negra	200.9 d	22.4 d	126.3 c	65.10 c
	15F30005	265.3 b	30.8 c	178.3 c	78.10 c
	15F30006	262.1 b	29.3 c	228.5 c	82.87 c
SWEET	BRS 511	197.8 d	16.2 e	387.8 a	195.06 a
	CMSXS 5027	205.9 d	24.8 d	286.2 b	113.65 c
	CMSXS 5030	214.2 d	23.8 d	395.6 a	155.36 b
	CMSXS 5043	241.7 c	29.3 c	208.2 c	80.90 c
	CMSXS 5045	244.4 c	28.7 c	219.4 c	87.72 c
BIOMASS	AGRI-002E	308.5 a	29.1 c	175.1 c	72.41 c
	BRS 716	289.4 a	26.9 c	153.7 c	74.61 c
	CMSXS 7501	242.6 c	25.8 c	153.0 c	71.21 c
	2019B008	266.6 b	42.1 a	138.0 c	52.88 c
	F	<0.01	<0.01	<0.01	<0.01
	CV (%)	3.93	7.65	17.00	16.24

[1/] DM: dry matter content in g kg^{-1} DM; BC: Buffering capacity in g kg^{-1} DM; WSC: water soluble carbohydrates in g kg^{-1} DM e FC: fermentation coefficient. * By the Scott-Knott test, means followed by the same letter constitute a statistically homogeneous group at 5% probability.

However, Parisotto (2020) found a similar value for BRS Ponta Negra, with 220.8 g kg^{-1} DM in a second crop test, corroborating with Macêdo et al. (2018), which observed 210.5 g kg^{-1} DM.

According to McDonald et al. (1991) and Muck and Pitt (1993), the DM content of the ideal forage, so that undesirable fermentations such as clostridial in the silage do not occur, is 300-350 g kg^{-1} DM, a value that differs from most of the results found. Values below the indicated can also increase effluent losses, reducing its nutritional value, as the effluent is composed of highly digestible nutrients.

For buffering capacity (Table 3), five groups of means were formed (P<0.01). The commercial material BRS 511 had the lowest

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content, 16.2 g kg^{-1} DM.

At a low buffering capacity, the speed of pH drop is benefited, favoring that the ideal values for inhibition of microbial activity are reached faster, reducing DM losses. However, the pH may take longer to reach the recommended level at a high TC, leading to more significant DM losses (Reis et al., 2014).

One of the main components for a good fermentation inside the silo is the content of WSC that estimate the substrate for bacteria to carry out the fermentation processes. In the present work, three groups of means were formed ($P<0.01$), with the sweet BRS 511 and CMSXS 5030 having the highest mean, 371.7 g kg^{-1} DM (Table 3). As already explained, these materials have sweet and succulent stems, with high non-structural carbohydrates that remain in the form of soluble sugars, reflected in the WSC levels. According to Lourenço et al. (2007), sweet Sorghum may have DM sugar levels between 300 and 400 g kg^{-1} DM, similar to those found in this work.

The genotypes BRS 658, BRS 659, Volumax, BRS Ponta Negra, 15F30005, 15F30006, CMSXS 5043, CMSXS 5045, AGRI-002E, BRS 716, CMSXS 7501, and 2019B008 fell into the group with the lowest average of CHOs, with 178.6 g kg^{-1} DM (Table 3).

The sweet genotypes stood out in terms of WSC. However, care must be taken with their use for silage production, as they have low levels of dry matter and are susceptible to undesirable fermentations, such as alcoholic. However, the high content of WSC can provide enough substrate for a rapid drop in pH to occur, inhibiting other fermentations. It is assumed that a later harvest than that performed in the present work will be beneficial to increasing the DM content and reducing the risk of secondary fermentation. Therefore, further studies should be carried out on using these materials in animal feed and their epiphytic microbiota.

Studies with standard sorghum biomass genotypes for silage production are scarce, given the current demand for their use for animal feed. However, according to McCullough (1977), the minimum WSC content necessary for a good fermentation is between 60 and 80 g kg^{-1} DM, a value below that verified for all the materials studied.

Biomass materials can be an alternative for intensive systems despite having a lower nutritional value than sorghum developed for silage production. Thus, these materials can be an alternative for use in intensive systems, given that they are superior in production per unit of area, generating resource savings and crop area optimization. In addition, for some systems, such as strategic retention of animals for moderate gains or confinement, with intense demand, they can be used as a source of low-cost roughage for supplementation of animals if a correct diet balance is implemented.

For fermentation coefficient, three groups were formed ($P<0.01$), with the BRS 511 in the largest group, with an average of 195.06. In the smallest group, the cultivars BRS 658, BRS

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659, Volumax, BRS Ponta Negra, 15F30005, 15F30006, CMSXS 5027, CMSXS 5043, CMSXS 5045, AGRI-002E, BRS 716, CMSXS 7501 and 2019B008 with an average of 76.91 (Table 3).

Weissbach (1996) showed that forage presents satisfactory fermentation with FC above 45, a value lower than that observed in all cultivars, a fact that can be attributed to the compensation between DM and WSC in the materials, demonstrating that all due to this characteristic, are susceptible to be ensiled and produce silage with a good fermentation pattern.

The chemical characterization was also performed to obtain the materials' *in natura* characteristics before the ensiling process (Table 4). For crude protein, four groups were formed ($P<0.01$). The highest average, 69.7 g kg^{-1} DM, group was composed of the forages BRS 658, BRS 659, 15F30005, and 15F30006. The DM content in the present study corroborates Rodrigues Filho et al. (2006), which found 69.7 g kg^{-1} DM for the forage BRS 610, similar to BRS 658 and BRS 659.

The smallest group of CP was formed by the cultivars with biomass sizes CMSXS 5045, BRS 716, and 2019B008, with an average of 39.3 g kg^{-1} DM. The lower value can be attributed to lower panicle proportions detected when performing plant fractionation.

According to Church (1988), the diet of a ruminant animal must contain at least 70 g kg^{-1} DM of crude protein to provide nitrogen in adequate doses for the normal development of ruminal bacteria, a value observed only in BRS 658, BRS 659, 15F30005 and 15F30006.

Compared to commercial forage materials intended for silage production, the biomass materials BRS 716, AGRI-002E, CMSXS 7501, and 2019B008 showed a 30.34% reduction in crude protein content, as well as the dry stalk sweet CMSXS 5043 and 5045, with a reduction of 39.84%, while the new forage hybrids had similar contents.

For non-protein nitrogen, five groups were formed ($P<0.01$). The sweete material BRS 511 had the highest average, 345.7 g kg^{-1} CP, and the forages BRS 658 and 659 had the lowest, 179.6 g kg^{-1} CP.

Part of the protein in the sorghum grain forms a dense protein matrix composed of glutelins and prolamins rather than NPN (Rooney & Miller, 1981). Foods containing NPN are essential for the proper functioning of the rumen, as ruminants can convert them into protein. Microbial enzymes hydrolyze most dietary proteins into peptides and amino acids. Free amino acids are incorporated into microbial protein or deactivated by ammonia and volatile fatty acids, which can be absorbed in the rumen or used as carbon skeletons for amino acid synthesis (National Research Council, 1976).

Four groups were formed for the content of non-fibrous carbohydrates ($P<0.01$). With the highest average of 443.2 g kg^{-1} DM, the sweete materials BRS 511, CMSXS 5027, and CMSXS 5030 com assemble a group. The ones with the lowest average, composed of the

Table 4. Chemical composition of 15 sorghum genotypes cultivated in the first crop in Sinop/MT.

Aptitude	Genotype	CP	NPN	NFC	NDFap	ADFap	Lignin	iNDF	TDN
FORAGE	BRS 658	70.5 a	175.8 e	340.9 b	525.7 d	310.7 c	52.7 c	304.5 c	582.37 b
	BRS 659	71.3 a	183.4 e	381.0 b	484.6 e	285.8 d	49.1 c	231.5 d	590.48 b
	Volumax	61.9 b	284.9 c	269.7 c	592.4 b	349.4 c	44.4 d	247.4 d	571.48 b
	BRS Ponta Negra	63.2 b	256.2 c	309.7 c	564.5 c	342.8 c	53.1 c	311.3 c	575.94 b
	15F30005	68.2 a	239.2 d	327.0 b	543.5 c	328.9 c	51.9 c	294.1 c	575.39 b
	15F30006	68.9 a	216.9 d	366.3 b	495.7 d	287.3 d	42.7 d	286.2 c	604.15 b
SWEETE	BRS 511	57.8 b	345.7 a	446.0 a	424.5 f	235.4 d	34.2 d	283.3 c	651.88 a
	CMSXS 5027	54.2 c	239.8 d	418.5 a	456.1 e	273.5 d	41.8 d	260.4 d	622.59 a
	CMSXS 5030	51.1 c	261.2 c	465.1 a	426.7 f	257.6 d	42.6 d	271.7 d	643.45 a
	CMSXS 5043	46.5 c	229.6 d	236.6 d	666.9 a	409.1 a	61.4 b	372.8 b	530.66 c
	CMSXS 5045	35.2 d	207.8 d	226.8 d	692.0 a	426.1 a	69.1 b	378.3 b	520.97 c
BIOMASS	AGRI-002E	54.5 c	230.2 d	211.5 d	684.6 a	424.0 a	72.6 a	385.7 b	514.09 c
	BRS 716	39.8 d	253.7 c	219.8 d	698.7 a	450.5 a	80.6 a	430.3 a	513.64 c
	CMSXS 7501	52.1 c	272.2 c	264.0 c	627.6 b	409.1 b	51.9 c	436.7 a	559.98 b
	2019B008	42.8 d	305.1 b	205.9 d	694.8 a	436.5 a	78.9 a	452.9 a	501.20 c
	F	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	CV (%)	7.15	9.06	8.44	4.69	8.07	13.04	8.08	3.42

CP: crude protein, in g kg^{-1} DM; NPN: non-protein nitrogen based on total nitrogen; NFC: non-fibrous carbohydrates, in g kg^{-1} DM; NDFap: neutral detergent fiber, ash and protein free based on DM; ADFap: acid detergent fiber, ash and protein free based on DM; Lignin: in g kg^{-1} DM; iNDF: fiber in neutral detergent, indigestible based on DM e, TDN : total digestible nutrients, in em g kg^{-1} DM. * By the Scott-Knott test, means followed by the same letter constitute a statistically homogeneous group at 5% probability.

sweete CMSXS 5043, CMSXS 5045, and the biomass AGRI-002E, BRS 715, and 2019B008, obtained 220.1 g kg^{-1} DM. The NFC is a fraction easily and almost completely digested by most animals, and comprises organic acids, mono- and oligosaccharides, fructans, starch, pectin and other carbohydrates, except for hemicellulose and cellulose, found in the fraction of insoluble fiber in neutral detergent (iNDF) (Van Soest, 1993; Hall, 2003).

The higher levels of non-fibrous carbohydrates found in sweete sorghum cultivars can be attributed to the higher WSC contents in these cultivars. Conversely, the cultivars that showed the lowest levels, despite some being sweete, are materials with a standard size characteristic biomass and dry stem with lower levels of WSC.

In the neutral detergente fiber corrected for ash and protein (NDFap) levels, the formation of six groups was observed (P<0.01). The largest group, composed of the sweete CMSXS 5043, CMSXS 5045, and the biomass AGRI-002E, BRS 716, and 2019B008, obtained an average of 684.7 g kg^{-1} DM.

The smallest group of NDFap, with an average of 425.6 g kg^{-1} DM, was composed of the sweete BRS 511 and CMSXS 5030. The value observed for BRS 511 coincides with that found by Orrico Júnior et al. (2015), of 416.9 g kg^{-1} DM, without corrections for protein and ash. Van Soest (1994) reports that for good digestibility of materials for silage use, iNDF values should be from 550 to 600 g kg^{-1} DM and those values above correlate negatively with the voluntary consumption of dry mass by animals.

When compared with commercial forages, the NDFap contents of biomass materials (CMSXS 5043, CMSXS 5045, BRS 716, AGRI-002E, and 2019B008) showed an increase of 28.67%, while the new forages showed a reduction of only 2.74%, despite showing a larger size than the commercial ones. Furthermore, the CMSXS 7501 biomass genotype showed a lower increase than the others in its category, 17.48%. Finally, among the new sweets, it is worth mentioning CMSXS 5030, which showed a reduction of 20.13% in NDFap contents.

For acid detergent fiber corrected for ash and protein (ADFap), four groups were formed (P<0.01). The highest average was 429.2 g kg^{-1} DM in the group consisting of the sweete CMSXS 5043, CMSXS 5045, and the biomass AGRI-002E, BR 716, and 2019B008. The values found in the present work differ from the literature, with values between 369.0 g kg^{-1} DM and 535.1 g kg^{-1} DM (Netto et al., 2018; Simeone et al., 2018).

Contrary, the forages BRS 659, 15F30006 and the sweete BRS 511, CMSXS 5027, and CMSXS 5030 defined the group with the lowest average, 267.9 g kg^{-1} DM. The ADFap is inversely proportional to digestibility (Van Soest, 1994; Rosa et al., 2004), i.e., the lower the ADFap content, the greater the digestibility of the dry mass of the food (silage) by the animal, voluntary consumption.

In the lignin component, four groups were observed (P<0.01). The Biomass purposes materials BRS 716, AGRI-002E, and 2019B008, formed the group with the highest average, with 77.4 g kg^{-1} DM. Batista (2016) obtained a similar value (79.1 g kg^{-1} DM) for BRS 716 in research aiming to generate bioenergy.

The group with the lowest average for lignin, formed by the forages Volumax and 15F30006 and the sweete BRS 511, CMSXS 5027, and CMSXS 5030 41.1 g kg^{-1} DM, was more diversified. Caxito (2017), evaluating Sorghum for different purposes, found similar values, ranging between 26.2 g kg^{-1} DM and 47.7 g kg^{-1} DM for Volumax and between 27.9 g kg^{-1} DM and 38.9 g kg^{-1} DM for BRS 511, in biannual production in two different locations.

Compared with commercial forages biomass sorghum increased 57.19% in lignin contents. This increase is justifiable, considering

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that they are materials sensitive to the photoperiod and reach greater heights; consequently, they need lignin to avoid lodging. On the other hand, the new forages hybrids are taller than the commercial ones and showed a reduction of 2.94% in the contents. Despite their large size, the standard biomass sweete increased by 10.25%, a low value compared to the increase of conventional biomass.

Among these materials, it is worth mentioning the cultivar CMSXS 7501, a material with the *bmr* gene, which confers lower levels of lignin to Sorghum. Therefore, the material with the *bmr* gene and its conventional version, the BRS 716, were evaluated in the present work. The CMSXS 7501 presented 35.61% less lignin, which is significant considering using these materials for animal feed. According to Rodrigues et al. (2015), this reduction can reach 50% in the lignin content.

Of the cell wall components, lignin is the most recognized component for limiting the digestion of fibrous polysaccharides in the rumen (Van Soest, 1994). However, lignin plays a protective role on the cell wall components of plants, promoting resistance and physical resistance, increasing the hydrophobic and impermeable wall (Jung & Allen, 1995), justifying the values.

Four groups were formed for indigestible neutral detergent insoluble fiber ($P<0.01$). The group with the highest average, composed of BRS 716, CMSXS 7501, and 2019B008 biomass, presented 439.9 g kg^{-1} DM. On the other hand, the group composed of the forages BRS 659, Volumax, and the sweete CMSXS 5027 and CMSXS 5030 had the lowest average, 252.8 g kg^{-1} DM. In a study carried out by Caxito (2017), different values were found for BRS 716, ranging between 257.8 g kg^{-1} DM and 357.2 g kg^{-1} DM, and for Volumex oscillating between 233.8 g kg^{-1} DM and 321.9 g kg^{-1} DM.

When analyzing the lignin and iNDF contents, it is possible to observe that materials with higher amounts of lignin also present higher iNDF. The iNDF is constituted by the fraction of the plant cell wall that is not digested along the gastrointestinal tract (Sniffen et al., 1992).

Finally, three groups were observed ($P<0.01$). The group with the highest average, with 639.31 g kg^{-1} DM, was composed of the sweetes BRS 511, CMSXS 5027, and CMSXS 5030. With the lowest average, the group with the sweetes CMSXS 5043, CMSXS 5045, and the biomass AGRI-002E, BRS 716, and 2019B008 obtained 516.12 g kg^{-1} DM. Rodrigues Filho et al. (2006), evaluating BRS 506, a sweete material similar to BRS 511, found 633.5 g kg^{-1} DM, a content close to the present study.

The TDN is a way of expressing food energy used in an animal's diet. According to Keplin (1992), to be considered good quality, silage must present from 640 to 700 g kg^{-1} DM of TDN and, based on this, commercial sweet sorghum BRS 511 and the experimental CMSXS 5027 and CMSXS 5030 fit in. in that range.

When using commercial forages as a comparison, the genotypes with biomass

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aptitude (CMSXS 5043, CMSXS 5045, BRS 716, AGRI-002E, and 2019B008) showed 11.24% fewer TDN levels. This value can be justified by the high levels of NDFap, ADFap, and lignin, characteristic of these materials. New forages hybrids achieved an increase of 1.43%. The experimental biomass genotype CMSXS 7501, different from its category, showed an increase of 3.69%. Among these sweetes, it is worth mentioning CMSXS 5030, which, despite being larger, showed an increase of 10.66% in TDN levels, a relevant characteristic when the objective is to find materials that can be used in animal feed.

Conclusions

All genotypes analyzed were likely to be ensiled and promote silages with good fermentation patterns. The genotypes with biomass aptitude BRS 716 and AGRI-002E demonstrated superior productivity. The sweet materials CMSXS 5027 and CMSXS 5030 stood out in ensilability potential.

For all the variables, including the productive characteristics, it was observed that the hybrid CMSXS 5030 stands out in terms of productive potential and ensilability with a good fermentation pattern.

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