



Original article

Agronomic and bromatological evaluation of different sorghum genotypes

Avaliação agrônômica e bromatológica de diferentes genótipos de sorgo

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Abstract

Objective: to evaluate the responses of sorghum hybrids through their agronomic and nutritional characteristics and in situ dry matter digestibility. **Methodology:** the experiment took place in Janaúba, MG, using 13 varieties of forage sorghum, including BRS 655, Volumax and 11 hybrids resulting from crosses between three males and three females. In the field experiment, a randomized block design (RBD) was adopted with 13 genotypes and 3 replications, totaling 39 experimental units. Agronomic characteristics, bromatological composition and in situ digestibility were analyzed. The data was subjected to statistical analysis using SISVAR and the means were compared using the Scott-Knott test at a significance level of 5% ($p < 0.05$). **Results:** the results indicated that the VOLUMAX, 13F24019, 13F04006 and 13F24006 genotypes had a longer flowering period. In terms of green and dry matter production, genotypes 13F04006 and 13F24006 stood out with higher values. There were no significant differences in lignin and DIVMS content between the genotypes. **Conclusion:** it can be concluded that the most suitable genotypes for animal production are 13F04006 and 13F2406, due to their higher productivity, high protein content, lower lignin content and greater digestibility.

Keywords: Digestibility. Sorghum. Crude protein. FDA.

Resumo

Objetivo: avaliar as respostas de híbridos de sorgo, através de suas características agrônômicas, nutricionais e digestibilidade *in situ* da matéria seca. **Materiais e Métodos:** o experimento ocorreu em Janaúba, MG, utilizando 13 variedades de sorgo forrageiro, incluindo o BRS 655, Volumax e 11 híbridos resultantes de cruzamentos entre três machos e três fêmeas. No experimento de campo, adotou-se um delineamento de blocos casualizados (DBC) com 13 genótipos e 3 repetições, totalizando 39 unidades experimentais. Foram analisadas características agrônômicas, composição bromatológica e digestibilidade *in situ*. Os dados foram submetidos à análise estatística utilizando o SISVAR e as médias foram comparadas pelo teste de Scott-Knott em nível de significância de 5% ($p < 0,05$). **Resultados:** os genótipos VOLUMAX, 13F24019, 13F04006 e 13F24006 apresentaram um período de florescimento mais prolongado. Quanto à produção de matéria verde e seca, os genótipos 13F04006 e 13F24006 destacaram-se com valores superiores. Não foram observadas diferenças significativas nos teores de lignina e DIVMS entre os genótipos. **Conclusão:** os genótipos mais indicados para a produção animal são 13F04006 e 13F2406, devido à sua maior produtividade, teor proteico elevado, menor teor de lignina e maior digestibilidade.

Palavras-chave: Digestibilidade. Sorgo. Proteína bruta. FDA.

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Introduction

In Brazil, pasture is the most prevalent diet in ruminant farming. As such, the cultivation of forage plants plays a crucial role in livestock farming, being the main source of feed¹. To mitigate the impacts of seasonality on food supply, forage conservation has proven to be an essential alternative to guaranteeing the nutrition and continuity of animal production systems, especially during periods of pasture scarcity².

The Brazilian semi-arid region is characterized by specific climatic conditions, marked by a period of drought that lasts approximately 6 to 8 months throughout the year³. With this in mind, implementing sorghum in ruminant feed has become a viable alternative, as it is a plant with high energy, digestibility, and productivity that adapts well to hot, dry regions. Sorghum has shown excellent agronomic growth characteristics and a high production potential, both in southern and central Brazil and in the semi-arid areas of the northeast⁴.

Sorghum bicolor (L.) Moench from Africa and parts of Asia, known as sorghum, belongs to the Poaceae genus and is a C4 grass with high photosynthetic efficiency, which allows it to be highly tolerant of water scarcity and to grow crops at temperatures above 21 °C. It is a food species that stands out most because it is grown in hot, dry environments where many varieties of plants used for animal feed are unable to grow with a good volume of mass due to water stress⁵⁻⁶.

After corn, sorghum is the most important annual crop for silage production, as it allows for economically viable production with a good energy value and a protein content of up to 7%. In addition to its versatility in feeding, sorghum-based roughage can be added to feed or mixed with other forage crops, providing farmers with an excellent source of income. As such, it stands out for its hardiness, high biomass production, and high tolerance to water deficit⁶.

Due to Brazil's climatic diversity, research is needed to identify the best cultivar to use in each region, since a single cultivar does not behave in the same way in all the different regions. To avoid seasonal production, producers should look for forage species that offer nutritional quality, resistance to growing conditions, and high biomass production. Growing sorghum in the country helps to prevent problems related to frequent periods of drought, which cause animals to lack sufficient food throughout the year⁷.

This study aimed to evaluate the agronomic and nutritional characteristics of some sorghum genotypes grown in the city of Janaúba-MG.

Material and Methods

To conduct this study, thirteen sorghum genotypes were examined, including two commercial forage crops, BRS 655 and Volumax, as well as eleven hybrids (13F23019, 13F23028, 13F24005,

13F24006, 13F24019, 13F24028, 13F25005, 13F25006, 13F25019, 13F25028, 13F04006), originated by crossing three males and three females.

The 13 genotypes were planted on November 20, 2020, in the city of Janaúba-MG. Harvesting took place on March 5, 2021, after the first rain in the region. During the period between planting and harvesting, according to data from EPAMIG in Janaúba-MG, there was an accumulation of 238.6 mm of water. The genotypes were distributed in 39 experimental units, made up of 3 blocks, each containing 13 plots. The nitrogen fertilizer was spread in two stages, one-third at planting and the rest in top dressing 30 to 35 days after emergence, with a dose of approximately 70g of the fertilizer formulated at 20-00-20 per meter. The experiment was conducted under dry conditions, where supplementary irrigation was only used to establish the initial *stand* to avoid losing the experiment. Thinning was carried out 20 days after emergence, keeping approximately 12 plants per meter. Cultivation was carried out regularly, and harvesting took place shortly after the grains had matured to the milky/pasty stage.

Each experimental unit had six rows 6.0 meters long, spaced 0.7 meters apart. The genotypes planted were subjected to evaluations covering their agronomic, bromatological, and *in situ* digestibility aspects. The analyses were carried out on four rows of each plot, removing 1.0 meters from the ends of each row and the two side rows of each plot (borders). The agronomic characteristics were assessed in the two central rows, while the bromatological composition and *in situ* digestibility were tested in the two rows involved. The two central rows of each plot were used to determine the flowering age, measured in days from planting until the sorghum plant emitted the inflorescence. Plant height was measured from ground level to the top edge of 20% of the plants in each plot. Green matter production was obtained by weighing all the plants in the useful area of the plot after cutting 15 cm from the ground, while dry matter production was calculated from the green matter production and DM content of each genotype at the time of cutting.

For the nutritional assessment and leaf and stalk digestibility, ten plants were randomly selected from each bed. These samples were minced in a stationary mincer, mixed to ensure homogeneity, and placed in specific paper bags individually. The samples were then weighed and dried in a ventilated oven at 55°C for 72 hours. After drying, the material was removed from the oven and left at room temperature for 2 hours to stabilize the weight, followed by the determination of the percentage of dry matter.

The samples were sent to the food analysis laboratory at the State University of Montes Claros (Unimontes) Janaúba-MG campus, where they were separated and prepared for analysis. The material was then ground in a "Willey" type mill with a 1mm-diameter sieve and stored in polyethylene containers for subsequent analysis.



To determine *in situ* digestibility, sorghum samples were packed in TNT-type synthetic fiber bags with a grammage of 100, respecting the ratio of 20 mg of ms/cm² of the bag's surface area⁸. The TNT bags were tied and fixed to a nylon rope and introduced into the rumen of an adult bovine with a fistula. An incubation period of 144 hours was adopted, with the bags packed in duplicate. At the end of this period, the bags were removed from the rumen, washed in running water until they were clean, and then dried.

Dry matter (DM) was determined in an oven at 55°C for 72 hours, following the methodology described by Detmann *et al.*⁹. To assess *in situ* digestibility, data were obtained from the difference in weight of the material before and after rumen incubation, expressed as a percentage.

The data were submitted for statistical analysis using the System for Analysis of Variance (SISVAR)¹⁰. The *Scott-Knott* test was used to compare means at a significance level of 5% ($p < 0.05$).

Results

When analyzing the green matter production (“PMV”, in Portuguese) of the genotypes evaluated, there was a statistically significant difference between the materials ($p < 0.05$), as shown in Table 1. Genotypes 13F04006 and 13F24006 were similar to each other and superior to the others, with averages of 64.08 and 66.85 t ha⁻¹, respectively. This same trend can be seen in dry matter production (“PMS, in Portuguese”), where there is also variation between the materials ($p < 0.05$). Genotypes 13F04006 and 13F24006 showed similar results to each other and were superior to the others, with averages of 19.90 and 21.38 t ha⁻¹, respectively. Furthermore, when evaluating the genotypes, there was a significant variation between them ($p < 0.05$) concerning the number of days to flowering.

Table 1. Production of green matter (PMV), production of dry matter (PMS), flowering (FLOR), and plant height (ALTPL) of thirteen sorghum genotypes. Janaúba-MG.

Genotypes	PMV (t ha ⁻¹)	PMS (t ha ⁻¹)	FLOR(d)	ALTPL(m)
13F24005	28.28 c	7.95c	86.00 d	2.30 d
13F24028	29.74 c	9.07c	86.00 d	1.96 e
13F23019	31.70 c	9.11c	92.00 c	2.16 d
13F23028	33.17 c	9.66c	90.66 c	2.10 e
13F25028	34.03 c	9.85c	94.00 d	2.61 b
13F25019	34.06 c	11.59c	90.33 c	2.48 c
13F25005	34.28 c	10.99c	90.66 c	2.41 c
13F25006	36.51 c	11.32c	92.00 c	2.75 b
BRS 655	39.76 c	12.64c	82.00 e	2.45 c
VOLUMAX	40.25 c	11.66c	100.66 a	2.80 b
13F24019	54.41 b	16.55 b	94.00 b	3.73 a
13F04006	64.08 a	19.90 a	95.33 b	3.70 a
13F24006	66.85 a	21.38 a	94.00 b	3.53 a

CV (%)	13.06	16.21	1.86	4.54
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Averages followed by lowercase letters in the column differ by the *Scott-Knott* test at the 5% probability level. CV=Coefficient of variation.

The VOLUMAX, 13F24019, 13F04006, and 13F24006 genotypes had a longer flowering period compared to the others. There was no significant variation between these genotypes in terms of height, which ranged from 1.96 to 3.73 m ($p < 0.05$). On the other hand, genotypes 13F04006 and 13F24006 were similar to each other and superior to the others, with averages of 64.08% and 66.85%, respectively, for green matter production (PMV), as detailed in Table 1.

Table 2 shows that for the dry matter (DM) and mineral matter (MM) content of the sorghum genotypes, there was no statistically significant difference ($p > 0.05$), with averages of 30.48% and 6.28%, respectively. However, about crude protein, genotypes 13F24005, 13F23019, 13F23028, 13F25005, 13F04006, and 13F24006 showed higher values than the others ($p > 0.05$), as shown in Table 2. All the genotypes tested had relatively high neutral detergent fiber (NDF) contents, above 40%, which is in line with the dry matter contents. As for acid detergent fiber (FDA), the materials evaluated did not differ significantly ($p < 0.05$).

Table 2. Average dry matter (DM), mineral matter (MM), crude protein (CP), neutral detergent insoluble fiber (NDF), and acid detergent insoluble fiber (ADF) content of thirteen sorghum genotypes (data expressed in dry matter). Janaúba-MG.

Genotypes	DM (%)	MM (%)	CP (%)	FDN (%)	ADF (%)
13F24005	28.06 a	6.81 a	6.99 a	57.34 a	33.81 a
13F24028	28.73 a	5.81 a	4.66 b	57.07 a	32.59 a
13F23019	28.93 a	5.19 a	7.75 a	59.79 a	35.08 a
13F23028	28.73 a	5.06 a	7.87 a	49.90 b	31.38 a
13F25028	30.53 a	6.22 a	4.43 b	48.67 b	32.46 a
13F25019	34.00 a	7.00 a	4.37 b	51.75 b	33.33 a
13F25005	32.11 a	5.96 a	7.13 a	60.68 a	30.66 a
13F25006	31.06 a	6.11 a	5.76 b	58.98 a	34.28 a
BRS 655	31.83 a	5.97 a	5.12 b	58.00 a	31.84 a
VOLUMAX	28.90 a	5.65 a	3.38 b	58.58 a	34.81 a
13F24019	30.20 a	5.58 a	5.43 b	47.12 b	33.87 a
13F04006	31.06 a	7.42 a	6.73 a	56.36 a	31.90 a
13F24006	31.00 a	5.52a	8.35 a	61.72 a	31.89 a
Average	30.48	6.28	-	-	32.91
CV (%)	7.57	32.64	19.05	8.32	5.70

Averages followed by different lowercase letters in the same column differ ($P < 0.05$) by the *Scott-Knott* test. CV=Coefficient of variation.

There was no significant difference between the genotypes in terms of the lignin content found ($p > 0.05$), with an average of 6.83. The same pattern was applied to dry matter digestibility (DIVMS), with an overall average of 77.69%. However, the digestible dry matter production (DDSM) values of

the genotypes evaluated were different from each other ($p < 0.05$), with 13F04006 standing out with 12.98 t ha^{-1} , and genotype 13F24006 with 13.63 t ha^{-1} (Table 3).

Table 3. Average lignin content (LIG), in situ dry matter digestibility (ISDMD), and digestive dry matter production (DDMP) of thirteen sorghum genotypes (data expressed in dry matter).

Genotype	LIG (%)	ISDMD (%)	DDMP(t ha^{-1})
13F24005	6.64 a	74.36 a	5.48 c
13F24028	6.19 a	76.29 a	5.69 c
13F23019	6.31 a	76.54 a	5.85 c
13F23028	6.75 a	77.12 a	6.45 c
13F25028	7.14 a	77.32 a	6.97 c
13F25019	6.75 a	77.45a	7.37 b
13F25005	7.23 a	77.65a	7.83 b
13F25006	6.51 a	78.41 a	8.91 b
BRS 655	7.72 a	78.42 a	8.55 b
VOLUMAX	6.69 a	78.73 a	7.45 b
13F24019	6.80 a	78.88 a	9.09 b
13F04006	6.91 a	78.93a	12.98 a
13F24006	7.16 a	79.89 a	13.63 a
Average	6.83	77.69	-
CV (%)	12.21	2.42	15.12

Averages followed by different lowercase letters in the same column differ ($P < 0.05$) by the *Scott-Knott* test. CV=Coefficient of variation.

Discussion

Due to its sensitivity to photoperiod, sorghum develops variably depending on the region where it is grown, resulting in a variation in forage yield between the materials evaluated. In a study of the agronomic characteristics of five sorghum genotypes, the authors recorded a green matter production (PMV, in Portuguese) of between 37.18 and $52.14 \text{ t ha}^{-111}$. In this experiment, only four of the genotypes evaluated reached an average of more than 40 t ha^{-1} , namely Volumax, 13F24019, 13F04006, and 13F24006.

When evaluating the genotypes, there was significant variation ($p < 0.05$) in the number of days to flowering. The VOLUMAX, 13F24019, 13F04006, and 13F24006 genotypes took longer to enter this phase. This may explain the superiority of these materials in terms of dry matter production (DMP) since genotypes with a later cycle tend to be more productive due to a longer vegetative phase¹².

Among the genotypes analyzed, there was a variation in the average height values, ranging from 1.96 to 3.73 m ($p < 0.05$). Thus, genotypes 13F24019, 13F04006, and 13F24006 stood out from the others, while hybrids 13F24028 and 13F23028 had the shortest lengths. In a study of different sorghum genotypes, an overall average height of 2.15 m was recorded, with the tallest reaching 2.61 m and the shortest reaching 1.24 m^{13} .



When investigating the performance of forage sorghum hybrids in three different cuts, a higher green mass yield was observed in the cuts from regrowth in Presidente Prudente, SP¹⁴. Although this variable is correlated with productivity, it is important to consider the allocation of structures in the biomass composition. Although the plant structures were not separated in this study, it is known that in tall forage sorghum, there is greater biomass production in the leaves and not in the stalk compared to the participation of panicles¹¹.

In a study aimed at assessing the productivity of Volumax sorghum in the northern region of Paraná, green mass production of up to 59.8 t ha⁻¹ and 17 t ha⁻¹ of dry matter was observed for forage sorghum¹⁵. The researchers recorded an average production of 8.7 t ha⁻¹ of dry matter, possibly due to the prevailing climatic conditions during the winter period, characterized by lower rainfall and lower temperatures.

For a long time, sorghum varieties have been selected for silage based solely on the production of green mass per hectare, changes that reduce costs per ton of green matter produced, without considering the quality of the resulting material. These cultivars generally had characteristics such as tall size, long cycle, and low grain yield. However, over the years, the importance of grain and dry matter content has been revealed, as they are responsible for increasing dry matter production and determining where nutrients are concentrated.

Estela *et al.*¹⁴ reported even higher productivity values for Volumax sorghum, with 73 t ha⁻¹ of green mass and 19 t ha⁻¹ of dry matter. The different morphological and qualitative characteristics may explain the variations in dry matter production observed in this experiment. Genotypes 13F24019, 13F04006, and 13F24006 had higher averages than those mentioned in the aforementioned studies, with 16.55, 19.90, and 21.38 t ha⁻¹ of dry matter, respectively.

In sorghum, plant height is proportional to dry matter production and inversely proportional to panicle percentage, with the rate of panicle decrease being lower in low and medium hybrids and higher when plant height exceeds three meters¹³.

The dry matter (DM) percentage of sorghum varies according to the age at which it is cut, the composition of the thatch, and the proportion of the various constituents of the plant, such as leaves, thatch, and panicle¹⁶. Variations in the proportions of plant parts, such as the percentage of thatch and panicle, have a significant influence on the dry matter content of the whole plant, rather than the moisture content¹⁷. Quality silage should have a dry matter content of between 30 and 35%¹⁸. Given this, it can be seen that the genotypes 13F25028, 13F25019, 13F25005, 13F25006, BRS 655, 13F24019, 13F04006 and 13F24006 have average dry matter contents of between 30 and 35%, with values of 30.53%, 34.00%, 32.11%, 31.06%, 31.83%, 30.20%, 31.0% and 31.00% DM, respectively, highlighting ideal characteristics for producing high-quality silage.

On the other hand, contents higher than 35% can compromise the quality of the silage due to the greater presence of air. Materials with a higher moisture content are more susceptible to compaction¹⁹. In a study on the chemical composition of different sorghum hybrids, dry matter contents of 32.8% and 36.6% were observed²⁰.

Sorghum Sudanese L. is a variety of forage sorghum. Variations in the percentage of dry matter (DM) from 23.25% to 33.34% were observed for the Ponta Negra and IPA 1011 cultivars, respectively, values lower than those found in this study²¹. As for the Volumax genotype, a DM content of 30.1% was recorded, higher than that observed in this study for the same material²².

Based on the mineral matter percentages shown in Table 2, the genotypes showed no significant differences between themselves ($p>0.05$), ranging from 5.06% (13F23028) to 7.42% (13F04006), with an average of 6.28%. Mineral matter levels are indicative of the number of minerals present in forage. However, high levels may suggest a high silica content, which has no nutritional value for animals. Although mineral matter indicates the presence of minerals in the feed, this index does not provide details about which minerals are present and in what proportions. Normally, foods of animal origin are rich in calcium and phosphorus, while plant foods tend to have a lower mineral matter content²³.

The average crude protein (CP) values varied between the genotypes evaluated ($p<0.05$), as shown in Table 2, with a range of 3.38% to 8.35% and an average of 6.00%. When analyzing these values, it can be seen that a minority of the materials developed reached the ideal levels of CP to satisfy the nitrogen requirements of the rumen microbiome and ensure proper rumen function, which is at least 7%. The differences in the average levels of CP can be attributed to the different concentrations of the panicle fraction in the whole plant. An average content of 82.6 g kg⁻¹ was observed in the first cut of Volumax, in a production system similar to the one in this study²⁴. However, other authors have observed more significant variations in crude protein content in the aerial part of Volumax, with content ranging from 55.8 to 69.4 g kg⁻¹¹⁵.

Neutral detergent fiber (NDF) values ranged from 47.12% to 61.72%, with an average of 55.84%. Genotypes 13F24005, 13F24028, 13F23019, 13F25005, 13F25006, BRS 655, VOLUMAX, 13F04006 and 13F24006 had higher values than the others. The NDF content should be between 50% and 60%.¹⁹ Even if a material has a value higher than 60%, it doesn't necessarily differ from the others that are within the suggested limit. It's important to note that NDF is directly related to the speed at which food passes through the digestive tract, and the lower the level of NDF, the higher the dry matter intake.

Similarly, the neutral detergent fiber (NDF) content is directly related to several factors, including the cultivar's cycle, night temperatures, and soluble carbohydrate content, among others. In another study, there were no statistically significant differences between genotypes when it came to

NDF content in silage, with an average value of 68.63%, and results ranging from 57.71% to 74.44%²⁵. In another study, an average NDF content of 63.82% was observed among 25 cultivars, ranging from 56.64% to 76.12%²².

The acid detergent fiber (ADF) values were comparable between the genotypes evaluated ($p>0.05$), with an average of 32.91% and a range of 30.66% to 35.08%. High levels of ADF make it difficult for the rumen bacteria to break down the feed and digest it¹³. An analysis of the ADF provides an estimate of the total cellulose and lignin content of the sample and is inversely related to the digestibility of dry matter¹⁹. In another study, the authors found an average of 36.89% ADF in 25 varieties, with the lowest value recorded at 30.56% and the highest at 45.09%²². As for the ADF values, the higher ones could also be due to the lignin content, which would make the forage more indigestible for the animals. In comparison, the bromatological evaluation of silage from different sorghum genotypes in Alegre/ES²⁵ showed an overall average of 41.41% ADF for the 25 varieties tested, ranging from 36.34% to 45.63%.

The genotypes ($p>0.05$) showed no significant differences in terms of lignin content, maintaining an average of 6.83. Lignin plays a crucial role in limiting the digestion of cell wall polysaccharides and reducing the nutritional value for ruminants and is considered the most characteristic factor related to digestibility²⁶. Determining lignin levels is fundamental to understanding how the animal uses the forage, since the lower the lignin content, the more efficient the process of handling the food in the rumen tends to be²⁷.

There was no discrepancy in the *in situ* dry matter digestibility (ISDMD) values between the genotypes ($p>0.05$), maintaining an average of 77.69%. All the genotypes had ISDMD values above 50%, indicating good rumen digestibility, which suggests efficient nutrient absorption. Other authors have reported values of 53.57% and 52.74% for the *in situ* digestibility of dry matter in forage sorghum and dual-purpose silages, respectively²⁸. In an experiment carried out at Embrapa Cerrados (Planaltina-DF), ISDMD values of between 57.9% and 63.9% were found for sorghum planted in the harvest season and between 59.4% and 67.7% in the off-season²⁹. Despite the high values of neutral detergent fiber (NDF) and acid detergent fiber (ADF), there was no impairment of the *in situ* digestibility of dry matter, which can be explained by the high hemicellulose content, highlighting the importance of evaluating the composition of fiber in animal feed.

The lowest dry matter production ("PMS") values were observed in hybrids 13F24005 and 13F24019, ranging from 5.48 to 9.09 t ha⁻¹, respectively. The "PMS" values presented by these larger materials can be used to explain the higher digestible dry matter production (DDMP) values attributed to the experimental hybrids 13F04006 and 13F24006.

The production of digestible dry matter depends not only on the amount of dry matter produced by the forage but also on its digestibility. Therefore, the DDMP combines the volume and



quality of production, balancing the nutritional value. In essence, DDMP is the result of multiplying dry matter production by dry matter digestibility, representing the amount produced in the area and supplied as nutrients to the animals³⁰.

Conclusion

Genotypes 13F04006 and 13F24006 stand out for their high nutritional value in the soil and climate conditions of Janaúba-MG.

Authors' contribution

The authors approve the final version of the manuscript and declare themselves responsible for all aspects of the work, including ensuring its accuracy and integrity.

Conflict of interest

The authors declare no conflicts of interest.

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