

## Multivariate analysis of sorghum hybrids cultivated in the semiarid region

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### ADDITIONAL KEYWORDS

Grouping.  
Principal component.  
*Sorghum bicolor*.  
Ward.

### PALAVRAS CHAVE ADICIONAIS

Agrupamento.  
Componentes principais.  
*Sorghum bicolor*.  
Ward.

### INFORMATION

Cronología del artículo.  
Recibido/Received: 01.05.2020  
Aceptado/Accepted: 02.10.2020  
On-line: 15.01.2021  
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### INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) moench) belongs to the Poaceae family and is a cereal with high genetic variability. It can be used for the production of hay, silage, grains, for cutting, and grazing. An alternative in regions of semi-arid climate is the silage of sorghum, due to its phenological characteristics, ease of sowing, handling, harvesting and storage, besides its great nutritional value and chemical characteristics of the plant. The indication of hybrids adapted to regions of semi-arid climate is extremely important for the correct use

### SUMMARY

The objective of this study was to evaluate the agronomic characteristics of the plant and silage based on the principal component analysis of the clusters, dispersion plot and genetic correlation between Sorghum (L.) bicolor hybrids. Twenty sorghum hybrids were used in a randomized blocks design with three replications. The number of tillers, total plant height, leaf/stem and live matter/dead mass ratios, and the dry matters of leaf, stem, panicle and grains were evaluated. The means were compared using the Student Newman Keuls (SNK) test at a significance level of  $P < 0.05$ . Three principal component analysis were responsible an accumulation of about 67% of all phenotypic diversity (number of tillers, lodging and total green forage mass). There was a positive and strong correlation between the productivity variables (green forage mass with height, leaf/stem ratio, leaf dry mass). There was genetic variability within the groups, indicating that some hybrids can be highlighted by agronomic characteristics (number of tillers number, lodging, total green forage mass, total dry forage mass, height, leaf/stem ratio, dead material, leaf dry mass), and thus group III (12F042224, FEPAGRO 11.9929012, 9929026, SF 25, 947216, 12F042150, 9929012, PROG 134 IPA) presented the hybrids more productive and more suitable for the production of silage in semi-arid regions, among the four groups

### Análise multivariado de híbridos de sorgo cultivados no semiárido

### RESUMO

O objetivo deste estudo foi avaliar as características agrônômicas da planta e da silagem com base nos principais componentes dos agrupamentos, gráfico de dispersão e correlação genética entre híbridos de sorgo. Vinte e três híbridos de sorgo foram utilizados no delineamento de blocos casualizados com três repetições. Foram avaliados o número de perfilhos, altura total das plantas, relação folha / caule, relação matéria viva / massa morta, e as matérias secas de folha, caule, panícula e grãos. As médias foram comparadas pelo teste Student Newman Keuls (SNK), com nível de significância de  $P < 0,05$ . Três componentes principais foram responsáveis por um acúmulo de cerca de 67% de toda a diversidade fenotípica (número de perfilhos, Acamamento e Massa de forragem verde total). Verificou uma correlação positiva e forte entre as variáveis de produtividade (massa de forragem verde com altura, relação folha / caule, massa seca de folhas). Houve variabilidade genética dentro dos grupos, indicando que alguns híbridos podem ser destacados pelas características agrônômicas (número de perfilhos, acamamento, massa total de forragem verde, massa seca total de forragem, altura, relação folha / colmo, matéria morta, massa seca de folha) sendo assim o grupo III (12F042224, FEPAGRO 11.9929012, 9929026, SF 25, 947216, 12F042150, 9929012, PROG 134 IPA) apresentou os híbridos mais produtivos e mais indicada para a produção de silagem em regiões semi-áridas, entre os quatro grupos.

of sorghum (Silva et al., 2017, p.16), aiming the increase of feed security for the herds.

For the cultivation of sorghum, agronomic characteristics such as the production of green and dry forage mass, plant height, chemical composition and silage quality, are important in the characterization of promising hybrids for animal feeding. In this case, it is necessary to know the genetic parameters related to these characteristics and their correlations, since the knowledge of the genetic association between them is highly relevant (Malebele et al., 2015, p. 207), to select the hybrids that are more suitable for semiarid regions.

Sorghum has chemical characteristics, similar to corn, that improves the nutritional value and high levels of soluble carbohydrates that improve the fermentation of silage, its use makes possible the replacement of corn in animal feeds with the reduction of costs and no loss of performance (SRICHUWONG et al., 2017, p.8)

Multivariate analysis techniques have been used for characteristics expressed by quantitative and qualitative variables and for evaluation of sorghum hybrids in the semi-arid region. The determination of genetic divergence with the use of multivariate analysis may allow the identification of genetic variability sources. The best application is the study of sets of variables associated with the superiority of the hybrids, grouping and importance of the variables for the study of genetic diversity. It is possible to identify superior individuals through the mean test through the significant difference, who was better for certain characteristics (Jimmy et al., 2017, p.48). This quantification can be performed using different techniques, including agronomic, morphological, and molecular characteristics. For quantitative variables, the variability can be accessed using measures of dissimilarity, such as: Euclidean distance, principal component analysis, canonical variables and agglomerative methods (Cruz and Regazzi, 2001, p.390) can also be used as tools to identify superior genotypes. The Ward grouping method (Ward, 1963) called minimum variance (Mingoti, 2005, p.297) forms clusters by maximizing homogeneity, aiming to minimize the sum of squares of the residuals within the cluster.

Thus, this study aimed to evaluate the agronomic characteristics of the plant and silage based on the principal component analysis, dispersion plot, and genetic correlation between forage sorghum hybrids.

## MATERIAL AND METHODS

### EXPERIMENTAL SITE

The experiment was carried out in Alvorada do Gurgueia, Piauí. The city of Alvorada do Gurgueia is located at latitude 08°25'28" south and longitude 43°46'38" west, and altitude of 281 meters. The climate at the location is classified as BSh, hot semiarid, with summer rains and dry winter according to the Köppen classification of 1936, described by Medeiros et al. (2013, p.660) and Alvares et al. (2013, p.719). Data on rainfall, air relative humidity and maximum and minimum temperature during the experimental period from November 2014 to April 2015 can be observed in **Figure 1**.

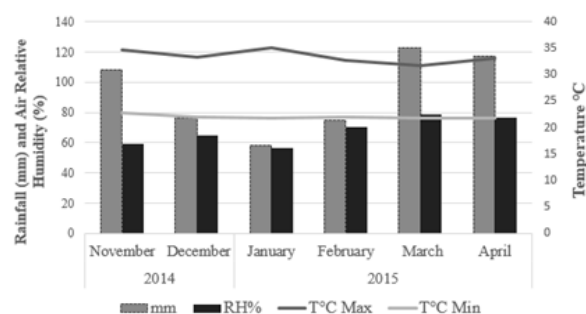
### EXPERIMENTAL DESIGN, AREA AND HYBRIDS TESTED

The experimental design was randomized complete blocks with three replicates. The total experimental area had 458.8 m<sup>2</sup>, divided into 75 plots of 2.8 m<sup>2</sup> each (2.8 m x 1 m) with a space between rows of 0.70 m, and the plots were separated by non-cultivated spaces of 0.5 m between them and 2.00 m between blocks.

The hybrids tested were: 9929036, 9929030, 12F042224, 12F042150, FEPAGRO18, FEPAGRO19, FE-

PAGRO11, 9929012, 9929026, 947216, 947030, 947254, 947072, 947252, SF15, SF11, SF25, PROG134IPA, 12F042226, 12F042422, 12F042496, BRS506, provided by Embrapa Corn and Sorghum, classified as dual-purpose sorghums.

### PLANTING AND FERTILIZATION



**Figure 1.** Meteorological data of the period of cultivation of the double purpose sorghum hybrids from November 2014 to April 2015 Source: <http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep>. Station: 82870 - Vale de Gurgueia Cristino Castro, Piauí (Dados meteorológicos do período de cultivo dos híbridos de sorgo de dupla finalidade de novembro de 2014 a abril de 2015 Fonte: <http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep>. Estação: 82870 - Vale de Gurgueia Cristino Castro, Piauí).

Before the experiment begun, a soil sample from the 0-20 cm layer of the experimental area was collected for analysis and chemical characterization (carried out at the Soil Analysis Center, CPCE). The soil was classified as dystrophic yellow latosol, following Rajj (1991), and had the following characteristics: pH = 5.40; phosphorus (P) = 9.6 mg dm<sup>-3</sup>; potassium (K) = 21.19 mg dm<sup>-3</sup>; calcium (Ca) = 2.4 cmol dm<sup>-3</sup>; magnesium (Mg) = 0.6 cmol dm<sup>-3</sup>; aluminum (Al) = 0.0 cmol dm<sup>-3</sup>; hydrogen + aluminum (H + Al) = 3.5 cmol dm<sup>-3</sup>; sum of bases (SB) = 3.1 cmol dm<sup>-3</sup>; Effective CEC (t) = 3.1 cmol dm<sup>-3</sup>; CEC at pH 7.0 (T) = 6.5 cmol dm<sup>-3</sup>; saturation (V) = 46.8%, saturation by aluminum (m) = 0.0%, and organic matter (OM) = 0.0%.

Based on the soil base saturation and crop requirements, it was not necessary to perform soil correction based on the soil base saturation. For the base fertilization 50 kg N ha<sup>-1</sup> (urea), 50 kg K ha<sup>-1</sup> (potassium chloride), and 30 kg Pha<sup>-1</sup> (single superphosphate) was applied, following the recommendations of (Sousa and Lobato, 2004, p.177). Planting was done at the beginning of the rainy season by sowing 20 seeds m<sup>-1</sup>.

### ASSESSMENT OF GROWTH CHARACTERISTICS AND HYBRIDS PRODUCTION

Evaluations were carried out based on grain maturation stage, considering the dough stage reached at different times. The plant was cut manually using a machete (Tramontina®) at a height of 10 cm above the soil, disregarding the lateral lines (considered bordering area) and 0.5 m from the extremities of the two central rows. Plants from the usable area of each plot (2 central linear meters) were used for the evaluation of the following variables: number of tillers; plant height; percentages of leaf, stem, panicle, grain and dead ma-

terial (dry or dead components); leaf:stem ratio (L:S); live:dead material ratio (LM:DM); total fresh and dry matter production; and production of leaf, stem, panicle, grain and dead material ( $\text{t ha}^{-1}$  DM).

The sorghum hybrids of double purpose were planted on November 15th, 2014, with harvesting and growing periods outlined as follows: hybrids 9929036, 9929030, 9929026 and 12F042226 were cut on March 2nd, 2015 with cycle of 105 days; hybrids 12F042224, 12F042150, FEPAGRO18, FEPAGRO19, FEPAGRO11, 9929012, 947216, 947030, 947072 and 947252 were cut on March 14th, 2015 with cycle of 119 days; hybrids 947254 and 12F042066 were cut on March 22nd, 2015 with cycle of 126 days; hybrids SF11, PROG134IPA, 1141570, 1141562 and BRS506 were cut on March 28th, 2015 with cycle of 132 days and hybrids SF15 and SF25 were cut on April 4th, 2015 with cycle of 138 days according to the phenological stage of the plant.

Number of tillers per linear meter was calculated based on the average of the total number of tillers in the usable plot area. Height was considered the average height of five plants chosen at random, measured with a steel measuring tape. The plants present within the usable area were harvested and weighed on a digital scale, which revealed the fresh mass.

For the morphological traits, two plants were collected from the usable plot area and separated into leaves, stems, dead mass and panicles, which were weighed individually to determine fresh weight. The samples were then dried in a forced-air oven at  $55\text{ }^{\circ}\text{C}$  for 72 h to determine the dry weight, as proposed by the Association of Official Analytical Chemists [AOAC] (1990)

#### MULTIVARIATE ANALYSIS

After collection, the data were stored in electronic spreadsheets for later analysis, using the statistical software SAS (Statistical Analysis System). The descriptive statistical analyses (mean, standard deviation and coefficient of variation) were performed through the MEANS procedure, the analysis of variance was performed by the PROC GLM and the means were compared using the Student Newman Keuls test at 5% of significance; the frequencies of the morphological characteristics were analyzed with the FREQ procedure, and the correlations between the measured characteristics were calculated using the CORR procedure of the same software.

For the study of phenotypic diversity, an analysis of principal component analysis was performed, using the SAS procedure PROC PRINCOMP, which allowed to group the hybrids based on the relation between the measured characteristics: number of tillers number, lodging, total green forage mass, total dry forage mass, height, leaf/stem ratio, dead material, leaf dry mass.

The eigenvalues of the correlation matrix corresponded to the variances of each component, and the normalized eigenvectors corresponded to the weighting coefficients of the standardized characteristics. The relative importance of a main component was evaluated by the percentage of total variance that it explains, that is, the percentage of its eigenvalue in relation to the total eigenvalues of all the components.

The similarity was the relationship between the different hybrids, so that high similarity between these hybrids indicates that they are distant based on the morphological characteristics (Rencher, 2002). The Euclidean distance was used as dissimilarity index and the clustering was evaluated by the Ward method, where the lowest intra-cluster variance increase was calculated to generate the clusters and, consequently, the dendrograms.

Ward's method does not calculate distances between clusters. But, for the formation of the clusters, the maximization of homogeneity within the clusters was made, or minimization of total sums of squares within each cluster, also known as sum of squares of errors. At each step of the procedure, clusters were formed such that the resulting solution had the smallest sum of squares within clusters (Dias, 2009).

#### RESULTS

The descriptive analysis of growth and production grouped the hybrids into four clusters (**Table I**). The number of tillers showed significant differences ( $P < 0.05$ ), with clusters I, II and III showing the highest averages: 19.1, 20.5 and 15.4%, respectively, which is related to the morphological characteristics of these hybrids.

Cluster IV (947252) had the most productive hybrid regarding the yield of total green forage mass and total dry forage mass, presenting the following means  $67.8$  and  $36.1\text{ kg ha}^{-1}$ . This was due to the hybrid present in this cluster which also presented the highest plant height:  $234.8\text{ cm}$ , since the height of the sorghum is related to the productive characteristics (**Table I**). The production of forage sorghum hybrids can be altered by the handling adopted, in particular fertilization directly contributes to the increase in productivity and the agronomic characteristics of the plant (Nascimento et al., 2020 p.75). In this experiment, however, the handling was the same for all hybrids, the differences being attributed exclusively to genetic variation between plants and their interaction with the climate, mainly.

Regarding the stem dry mass and dead material, cluster IV (947252) presented the highest averages  $20.7$  and  $2.0\text{ t ha}^{-1}$ . As for grain dry mass, cluster II (12F042224, FEPAGRO19, 12F042496) presented the highest average  $2.0\text{ t ha}^{-1}$ , showing that the morphological characteristics of these hybrids influenced these results (**Table I**). Based on these results it can be noted that the growth characteristics are allied to production.

Considering a minimum threshold, three main components (CPs) (**Table II**) were responsible for an accumulation of about 67% of all phenotypic diversity observed among hybrids.

It was verified that the first main component formed by the agronomic characteristics total green forage mass, dry stem mass and total dry forage mass, explains 37% of the total variation, while the second main component formed by the agronomic characteristics of leaf / stem and mass grain dryness explains together with the first component an accumulated of 52%, and

the third main component formed by the lodging and dry mass characteristics of the leaf together with the other two components reached an accumulated 70% of expected variation (Table III). Demonstrating that there is a great variation between hybrids.

Since the principal component analysis analysis (MCA) is not correctly used for grouping, it was necessary a cluster analysis by the Ward method. The diversity verified with the principal component analysis analysis was confirmed by the cluster analysis by the

Ward method, in which the most similar hybrids are grouped together (Figure 3).

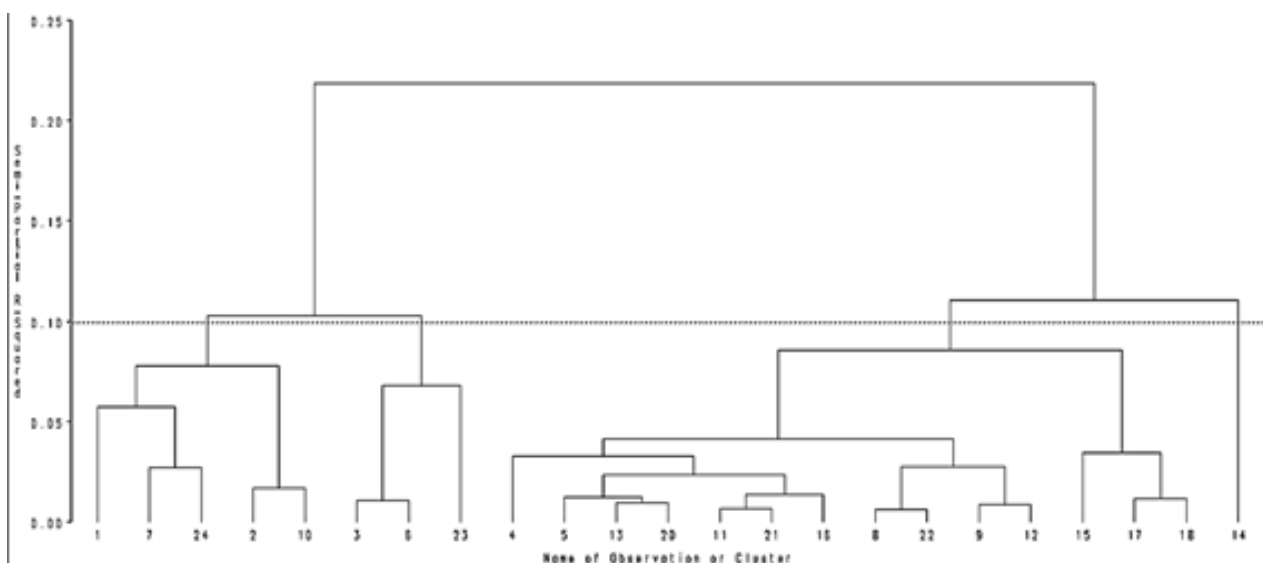
The formation of the clusters took into account the sum of squares of the deviations of the observations in relation to the clusters formed by the hybrids.

In the similarity dendrogram (Figure 3) it was observed that there is variability between clusters, but within each cluster there is a similarity among individuals, however variability may exist indicating

**Table I. Descriptive statistics of growth and production characteristics of 23 sorghum hybrids (Estatística descritiva das características de crescimento e produção de 23 híbridos de sorgo).**

Clusters		NT	LODG	TGFM	TDFM	H	L/S	DM	LDM
		----- % -----			---- Kg ha <sup>-1</sup> ----		--cm--	--- t ha <sup>-1</sup> -----	
I	Mean	19.1 a	9.6 a	29.6b	11.4b	148.0c	0.1a	4.0a	1.2a
	Maximum	32.0	50.0	53.5	21.8	190.4	0.9	8.4	2.9
	Minimum	11.0	0	14.4	5.2	94.6	0.09	0	0.4
	CV (%)	30.2	168.0	47.1	50.7	24.5	38.7	77.7	64.6
II	Mean	20.5 a	17.3a	42.7b	17.4b	181.4b	0.2a	5.1a	2.2a
	Maximum	25.0	54.5	58.4	25.0	211.6	0.3	10.6	4.5
	Minimum	16.0	0	22.1	10.5	170.0	0.04	0.8	0.4
	CV (%)	18.5	103.3	26.4	24.9	7.9	50.6	63.7	67.8
III	Mean	15.4 a	11.1a	49.9b	18.8b	188.5b	0.2a	4.0a	3.0
	Maximum	27.0	56.2	97.5	40.9	232.2	0.5	14.7	6.9a
	Minimum	8.0	0	15.6	6.0	140.0	0.1	0	0
	CV (%)	22.0	118.4	39.5	41.7	12.3	35.3	75.2	52.0
IV	Mean	13.0b	11.2a	67.8a	36.1a	234.8a	0.2a	5.5a	2.3
	Maximum	15.0	13.3	71.7	36.4	247.8	0.3	5.7	4.6a
	Minimum	11.0	9.0	63.9	35.9	221.8	0.2	5.4	0
	CV (%)	21.7	26.7	8.0	1.0	7.8	37.7	3.7	141.4

CV (%): Coefficient of Variation; NT: Number of Tillers; LODG: Lodging; TGFM: Total Green Forage Mass; TDFM: Total Dry Forage Mass; H: Height; L/S: leaf/stem ratio; DM: Dead Material; LDM: Leaf Dry Mass; SDM: Stem Dry Mass; DMDM: Dead Material Dry Mass; GDM: Grain Dry Mass. Means followed by equal letters in the column do not differ by the SNK test, at the significance level of 5%.



**Figure 3. Dendrogram of grouping by the Ward's method of the agronomic characteristics among the sorghum hybrids (Dendograma do agrupamento pelo método Ward das características agrônomicas entre híbridos de sorgo forrageiro)**

**Table II.** Eigenvalues associated to the main components obtained from the agronomic characteristics between the sorghum hybrids (Autovalores associados aos componentes principais obtidos a partir das características agrônomicas entre os híbridos de sorgo).

Main Component	Eigenvalue	Difference between eigenvalues	Simple Variation	Cumulative Variation
1	5.29	2.14	0.33	0.33
2	3.16	0.76	0.19	0.52
3	2.40	0.59	0.15	0.67
4	1.80	0.13	0.11	0.79
5	1.67	0.88	0.10	0.89
6	0.79	0.45	0.04	0.94
7	0.33	0.15	0.02	0.96
8	0.21	0.08	0.01	0.98
9	0.13	0.06	0.00	0.98
10	0.07	0.02	0.00	0.99
11	0.04	0.01	0.00	0.99
12	0.03	0.01	0.00	0.99
13	0.01	0.01	0.00	0.99
14	0.00	0.00	0.00	0.99
15	0.00	0.00	0.00	1.00
16	0.00	0.00	0.00	1.00

that some hybrids may stand out in comparison to the others regarding the agronomic characteristics. The groups were Cluster I: 9929036, FEPAGRO11, BRS506, 9929030 and 947216; Cluster II: 12F042224, FEPAGRO19 and 12F042496; Cluster III: 12F042150, FEPAGRO18, 947072, 12F042140, 947030, 12F042226, SF11, 9929012, 12F042422, 9929026, 947254, SF15, SF25 and PROG134IPA; and Cluster IV: 947252.

The results of the correlation analysis demonstrated by the correlation coefficients (Table IV), showed that the total green forage mass production had a positive and strong association ( $P \leq 0.05$ ) with total dry forage mass ( $r=0.89$ ), plant height ( $r=0.61$ ), stem dry mass ( $r=0.86$ ), and with leaf dry mass ( $r=0.60$ ); positive and weak association with leaf/stem ratio ( $r=0.22$ ) and grain dry mass ( $r=0.17$ ); and moderate association with dead material ( $r=0.44$ ). As for plant height, positive and weak associations were observed with leaf/stem ratio ( $r=0.11$ ) and leaf dry mass ( $r=0.29$ ), and positive and strong association with stem dry mass ( $r=0.63$ ). For grain dry mass there were significant but very weak and negative correlations with plant height ( $r=-0.02$ ), leaf/stem ratio ( $r=-0.35$ ), leaf dry mass ( $r=-0.24$ ), stem dry mass ( $r=-0.01$ ) and with dead material ( $r=-0.10$ ).

The grain yield presented a negative and non-significant correlation ( $p=0.9$ ) with height ( $-0.02$ ) and leaf/stem ratio ( $-0.35$ ) and also non-significant ( $p=0.26$ ) with leaf dry mass ( $-0.24$ ), stem dry mass ( $-0.01$ ) and dead material ( $-0.01$ ), and this can be explained by the energy balance of the plant.

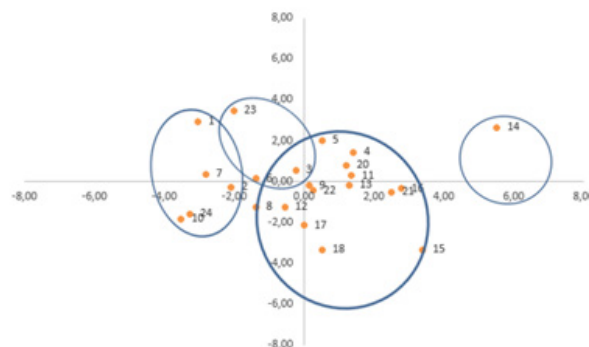
## DISCUSSION

The dry matter production of sorghum cultivars is directly related to the plant height, as the highest cultivars reach greater productivity (Albuquerque et al. (2012, p.72). On the other hand, the yield of DM ( $t\ ha^{-1}$ ) is a factor that is related to the management adopted and the productive capacity inherent to the species or hybrid (Table I Table I).

According to Campana (2010, p.103), the variables of higher weights in the first eigenvectors are considered more important for the study of diversity, when the eigenvalue explains a considerable fraction of the available variation, usually limited to a minimum value of 70%. Also, it was observed that there was variability within the clusters, which may indicate that some hybrids may stand out for the agronomic characteristics (Table II). The edaphoclimatic conditions of the region in addition to precipitation and temperature (Figure 1) affected productivity, knowing that sorghum supports production in dry and low-fertility soils due to a greater conversion of water into dry matter (Silva et al., 2018 p .9). Thus, the hybrids that stood out the most were the most adapted to the climatic conditions of the region.

Principal component analysis also demonstrated that there is a wide variation between hybrids. This, in turn, implies that several characteristics were involved in explaining this variation. These results were similar to the values found by Castrillon et al. (2017) who worked with different agro-morphological characteristics in sorghum (Figure 2).

From the point of view of hybrid selection and identification, this variation is favorable, indicating that the hybrids are different from each other, with the possibility of comparison and selection of those that present desirable characteristics, whether productive, morphological or both (Ferreira et al., 2003, p.1563) (Table III). Cluster IV was less expressive, formed by only one genotype: 947252, suggesting that it was the most divergent of the total analyzed. According to Benitez et al. (2011, p. 410) the occurrence of clusters with only one genotype shows wide divergence, since the hybrids in unit clusters are more dissimilar in relation to the set (Figure 3).



**Figure 2.** Dispersion plot based on the main components 1 versus the main components 2 of the agronomic characteristics of the sorghum hybrids (Trama de dispersão baseada nos principais componentes 1 versus os principais componentes 2 das características agrônomicas dos híbridos de sorgo).

**Table IV.** Correlation between the agronomic characteristics of the sorghum hybrids (Correlação entre as características agronômicas de híbridos de sorgo).

	TGFM	TDFM	H	L/S	LDM	SDM	DMDM	GDM
TGFM	1.00	<0.01	0.01	0.01	0.60	0.05	0.03	0.43
TDFM	0.89	1.00	<0.01	0.29	0.01	0.082	0.01	0.75
H	0.61	0.65	1.00	0.29	0.01	0.01	0.01	0.90
L/S	0.22	0.22	0.11	1.00	0.17	<0.01	0.22	0.26
LDM	0.60	0.51	0.29	0.79	1.00	<0.01	0.14	0.99
SDM	0.86	0.95	0.63	0.04	0.41	1.00	<0.01	0.62
DMDM	0.44	0.64	0.49	0.26	0.31	0.56	1.00	<0.01
GDM	0.17	0.06	-0.02	-0.35	-0.24	-0.01	-0.10	1.00

TGFM: Total Green Forage Mass; TDFM: Total Dry Forage Mass; H: Height; L/S: leaf/stem ratio; LDM: Leaf Dry Mass; SDM: Stem Dry Mass; DMDM: Dead Material Dry Mass; GDM: Grain Dry Mass.

The characteristic total green forage mass (TGFM) (Table IV) is strongly correlated with the production of total dry forage mass (TDFM), as one increases the other also increases and therefore the hybrids that have stood out for TGFM, also obtained high rates of TDFM (Tardin et al., 2013, p.103). These correlations were also observed in other studies, emphasizing the importance of knowing associative effects in the selection of genetic materials with desirable characteristics for the production of silage in the semi-arid region, corroborating with the results obtained by Perazzo et al. (2014,p.232) that evaluated the agronomic characteristics of 32 sorghum cultivars in the Brazilian semi-arid region and observed that the dry matter yield was correlated with the green matter yield ( $r = 0.8754^{**}$ ) and plant height ( $r = 0,61210^{**}$ ) at 5% of significance, which is a good indicative since there is no need to wait for the plant to dry out to know the amount.

The high positive and strong correlation of leaf/stem ratio, leaf dry mass and stem dry mass with the production of green forage mass is related to plant growth. The dry matter yield was positively correlated with the percentage of stem in green and dry matter, ( $r=0.86$ ) and  $0.95$ , respectively, which may be related to the higher participation of this fraction in the plant. The differences found for these components indicate that the environmental factors, such as the amount and distribution of rain, temperature and soil, had a strong influence (Figure 1) with the reduced rainfall distribution (Jimmy et al., 2017, p.48). Therefore, these are key variables in the selection of genetic material with suitable properties for silage quality.

The percentages of leaves and stem have a strict connection with plant height, as higher sorghums present higher dry matter yield. However, due to the higher percentage of stems in comparison to leaves and panicles, the nutritional value of the forage may be compromised. Among the proportions of plant components, in the present study a positive correlation was found between stem and plant height ( $r = 0.63$ ) (Carmo et al., 2020, p.424).

It was observed a positive and strong correlation between plant height and dry matter yield ( $r=0.61$ ).

This higher dry matter yield, as well as the increased plant height, may be associated with the sensitivity of the sorghum to the photoperiod, causing greater elongation between the plant nodes.

Plants of average heights present a more balanced distribution of its components, which characterizes the double purpose sorghum (Cunha & Lima 2010, p.702).

## CONCLUSIONS

There was genetic variability within the groups, indicating that some hybrids can be highlighted by agronomic characteristics (number of tillers number, lodging, total green forage mass, total dry forage mass, height, leaf/stem ratio, dead material, leaf dry mass) and thus group III (12F042224, FEPAGRO 11.9929012, 9929026, SF 25, 947216, 12F042150, 9929012, PROG 134 IPA) presented the hybrids more productive and more suitable for the production of silage in semi-arid regions, among the four groups.

## ACKOWLEGMENTS

The authors appreciate the support provided by the Study Group on Forage Crops (NUEFO) and thank the Coordination for the Improvement of Higher Education Personnel (CAPES) for the financial support.

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