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Agronomic evaluation of 32 sorghum cultivars in the Brazilian semi-arid region

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ABSTRACT - The objective of this study was to evaluate agronomic characteristics of 32 sorghum cultivars (*Sorghum bicolor* (L). Moench) in the Brazilian semi-arid region. The experimental design was set up in randomized blocks with three replications. Treatments were the 32 sorghum cultivars. The evaluated variables were: plant height, stem diameter, tiller density, number of green leaves per tiller, average leaf length, dry matter content, fresh matter production and dry matter production (DMP) in kg/ha, and the percentage of the components panicle, leaf blade and stem. To avoid associative effects due to the presence of positive correlation with DMP, the variables plant height, number of plants per hectare and fresh matter production were excluded for being part of the discriminatory variables of the cluster. Based on the cluster analysis and subjective cutting in 20% dissimilarity, five groups were hierarchically set up. It was not possible to find groups with higher values of panicle and DMP simultaneously; however, group number 5 met significant values for both variables, with mean values of 15,037.63 kg/ha of DMP and 11.36% of panicle, besides 13.65% of leaf. Groups 3, 4 and 5 show high potential for dry matter production, especially group 5. The presence of evident variation among cultivars allows for a selection of more productive and, thus, more suitable cultivars for silage production in semi-arid regions.

Key Words: dry matter, forage, panicle, plant height

Introduction

The scarcity of forage, aggravated in the dry season, and the low nutritional value of the forage in the natural pastures compromise growth and development of animals, resulting in decreased productivity, and decrease the production of milk and meat, which makes producers depend on the availability of conserved forages as hay or silage of cultivated fodder plant, and crop residues to feed cattle in semi-arid regions (Lima et al., 2004).

Sorghum (*Sorghum bicolor* (L). Moench) is a plant that can be compared to corn regarding its nutritional and agronomic values. Therefore, in terms of requirements and production, it appears to be an interesting alternative for the semi-arid regions, as it is more adapted to droughts due to its ability to recover and produce grain after a dry period, and produces more dry matter in areas with less fertile soils, as observed by Zago (1992).

Cândido et al. (2002) reported that the high demand for better-quality materials favored the emergence of numerous genotypes of sorghum, with specific size (high, medium, or low), cycle (early or late) and aptitude (forage, dual-purpose, or grain) traits, which have a strong influence on the nutritional value of the produced silage. One of the advantages of sorghum is its ability to regrow after the cutting of the original culture in the field, mainly when fertilization is employed (Afzal et al., 2012).

According to Neumann et al. (2002a), comparative studies of genotypes are important to contribute to the breeding programs and to recommend cultivars for producers whose silages have the best production:nutritional value ratio. Therefore, it is important to evaluate the genotypes available in the market seeking an appropriate balance between plant components, combined with high biomass productivity and nutritional value.

Thus, the evaluation of sorghum cultivars is especially important in northeastern Brazil, where half of the region is under the influence of adverse factors, classified as semi-arid, to some of which the sorghum is adapted (Mariguele and Silva, 2002).

The objective of this research study was to evaluate agronomic characteristics of 32 sorghum cultivars in the Brazilian semi-arid region.

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Material and Methods

The experiment was conducted at Estação Experimental Pendência, of Empresa de Pesquisa Agropecuária da Paraíba S.A (EMEPA), located in the municipality of Soledade, Paraíba State, Brazil (Coordinates 7º 8' 18" S and 36º 27' 2" W, altitude of 534 m).

Based on the Köppen classification, the climate of the region is a Bsh type (hot semi-arid), with rains from January to April, with average temperatures around 24 ºC, relative humidity around 68%, and average annual precipitation of 400 mm, with droughts almost all year.

The experimental design used was set up in randomized blocks with three replications. The experimental treatments were 32 sorghum cultivars developed by Instituto Agronômico de Pernambuco - IPA. The following cultivars were evaluated, identified by numerical order: SF-25 (Cultivar 1), 02-03-01 (Cultivar 2), 43-70-02 (Cultivar 3), 10-Ca84-B2Ca87-B2SB88-BCa89 (Cultivar 4), 25-Ca84-B2Ca87-B1SB88-BCa89 (Cultivar 5), 38-Ca84-B2Ca87-B2SB88-BCa89 (Cultivar 6), 41-Ca84-BCa87-B1SB88-BCa89 (Cultivar 7), 41-Ca84-BCa87-B2SB88-BCa89 (Cultivar 8), 46-Ca84-B2Ca87-B2SB88-BCa89 (Cultivar 9), 68-Ca84-BCa87-01SB88-01SB89 (Cultivar 10), SF 11 (Cultivar 11), 18-Ca84-B1Ca87-SB88B-Ca89 (Cultivar 12), 24Ca84-B1Ca87-B2SB88-BCa89 (Cultivar 13), 25Ca84-B1Ca87-B1SB88-BCa89 (Cultivar 14), 25Ca84-B2Ca87-B1SB88-BCa89 (Cultivar 15), 41Ca84-BCa87-B1SB88-BCa89 (Cultivar 16), 52Ca84-BCa87-B1SB88-BCa89 (Cultivar 17), 63Ca84-B1Ca87-B2SB88-BCa89 (Cultivar 18), 80Ca84-01Ca87-B1SB88-BCa89 (Cultivar 19), ST87-18, ST88-01, ST89-01 (Cultivar 20), Forrageiro Preto (Cultivar 21), Forrageiro Chocolate (Cultivar 22), Forrageiro Tese - 25 (Cultivar 23), Forrageiro Tese - 33 (Cultivar 24), Forrageiro Vermelho (Cultivar 25), T6 (467-4-2 R1) (Cultivar 26), T14 (02-03-01 R1) (Cultivar 27), T34 (Sudan 4202 R1) (Cultivar 28), Ponta Negra (Cultivar 29), Red Sorghum - Araripina (Cultivar 30), SF 15 (Cultivar 31), and IPA 2502 (Cultivar 32).

The sorghum cultivars were manually sown on March 5, 2011, in plots of 8.4 m^2 (4.2 × 2.0 m), with spacing of 70 cm between rows. Thinning was performed 30 days after planting to keep 12 plants per linear meter. Fertilization was applied based on the chemical properties of the soil (Table 1) of the experimental area using 50 kg of nitrogen, in the form of ammonium sulfate, 15 days after sowing.

The grains were harvested once they were in the pasty stage. As the experimental cultivars reached the point of harvest on different days, two harvests were made. The duration of the cycle from planting until harvesting was 78 and 88 days for the first and second harvests, respectively. In the first cycle, the following cultivars were harvested: 4, 14, 18, 23, 24, 26, 27, 28, 29, 30 and 32. And in the second cycle, cultivars 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 19, 20, 21, 22, 25, and 31 were harvested.

The total accumulation of precipitation in the first and second crops was 578 and 610 mm, respectively. The evaluation cut was made at 10 cm above the soil. The production of 2 meters of central lines was evaluated. The evaluated characteristics were: plant height, stem diameter, tiller density, number of green leaves per tiller, average leaf length, panicle length fresh matter production and dry matter production in kg/ha, and the percentage of components panicle, leaf blade and stem. The material collected from each plot was separated into panicles, leaf blade and stem, each fraction being weighed separately. A subsample of each fraction was dried at 65 °C until reaching constant weight, to estimate their dry matter (DM) content. From these data, the percentage of plant components was assessed based on DM. The fresh matter production (FMP) per hectare was obtained as the product between the production per linear meter cultivated and the total linear meters cultivated per hectare. The dry matter production (DMP) was estimated as the product between FMP and DM content, and subsequently converted to DMP per hectare. The tiller density was estimated s the number of tillers per cultivated linear meter and the total linear meters per hectare.

To identify the variables with associative effects Pearson's correlation analysis was conducted among all variables. The goal was to select discriminatory variables for a totally independent multivariate clustering analysis.

Multivariate analyses were performed to form homogeneous groups among 32 sorghum cultivars by Ward's method (minimum variance), adopting the mean Euclidean distance as a basic measure of dissimilarity with standardized data and using as discriminatory

Table 1 - Chemical properties of the soil of the experimental area

pH in H_2O	P	K^+	Na	H^++Al^{+3}	Al^{+3}	Ca^{+2}	Mg^{+2}	SB	CEC	V	OM
	mg/dm^3		cmolc/dm^3							%	g/kg
6.00	13.49	187.67	0.0	2.80	0.00	5.00	1.60	7.08	9.88	71.66	8.23

P - phosphorus; K^+ - potassium; Na+ - sodium; H^++Al^{+3} - potential acidity; Al^{+3} - aluminum; Ca^{+2} - calcium; Mg^{+2} - magnesium; V - base saturation; CEC - cation exchange capacity; OM - organic matter; SB - sum of bases.

variables those with a higher degree of independence between the agronomic characteristics and also with biological importance for food, animal nutrition and silage production.

Statistical procedures were performed with the aid of the SAEG software version 8.0, adopting 0.05 as the critical level of probability of type I error.

Results and Discussion

Dry matter production (DMP) was positively correlated with fresh matter production (r = 0.87), tiller density (r = 0.57) and plant height (r = 0.61) (Table 2).

These correlations are observed in the literature, emphasizing the importance of the knowledge and explanation of these associative effects to choose genetic materials with desirable characteristics for the production of silage.

The results obtained by Oliveira et al. (2005) showed that the greater plant height associated with the greater tiller density provided higher values for fresh matter production in sorghum hybrids. These values were reversed as the height and number of tillers per hectare decreased.

Monteiro et al. (2004) explained that although the plant height is a significant character for the production of biomass in forage sorghum, a greater height does not always imply higher dry matter production. For the occurrence of an increase in the weight of tillers, this variable should be related also to the stem diameter.

The variable number of tillers per hectare may be associated with dry matter production for representing the population of sorghum per unit area; however, it must be accompanied by other determining variables in increasing the volume of the tiller, such as stem diameter and plant height. Botelho et al. (2010) found higher values of number of tillers per hectare in conditions of regrowth compared with the first cut, but the production was higher for the first cut, showing that this variable alone is not efficient to increase the forage yield.

Zago (1992) explains that the percentages of leaves, stem, and panicles have a strict connection with plant height. A taller sorghum has higher dry matter production. Nevertheless, due to the higher percentage of stems in relation to leaves and panicles, the nutritional value of the forage may be compromised. Among the proportions of plant components, the present study found a positive correlation between stem (r = 0.26) and DMP, which is also associated with plant height (r = 0.36).

Cabral et al. (2003), testing different proportions of panicle in the composition of silage, found that adding panicles to sorghum silage resulted in an increase in non-fibrous carbohydrates, thus increasing its nutritional value. Neumman et al. (2002b) concluded that the panicle is the component of the sorghum plant that defines silage quality for presenting the greatest contents of DM, crude protein, and *in vitro* digestibility of dry matter, and lower neutral detergent fiber, acid detergent fiber, cellulose, and lignin, compared with the stem + leaves set.

The negative correlation between plant height and percentage of panicle (r = –479) showed that the plant size is decisive in the repartition of sorghum plant components. Taller plants usually have a higher biomass production and lower participation of panicle, being characterized as forage sorghum. For smaller plants, there is a higher percentage of panicles, which characterizes them as grain sorghum. Medium sizes provide a more balanced distribution between plant components, characterizing a behavior of dual-purpose sorghum.

It is important to highlight the neutrality of correlation (r = 0.07) between the variables percentage of panicle and panicle size, making it clear that panicle length has no effect on the set of plant components, so this component should be evaluated through weighing parameters.

Table 2 - Pearson's correlation coefficients among agronomic characteristics of 32 sorghum cultivars

	DMP	LB (%)	STEM (%)	PAN (%)	DM (%)	FMP	TD	PH	SD	NL	ALS	PS
DMP												
LB (%)	0.0407											
STEM (%)	0.2618	–0.5686										
PAN (%)	–0.347	–0.018	–0.8123									
DM (%)	0.3881	0.2728	–0.1967	0.0457								
FMP	0.8754	–0.1162	0.4045	–0.4093	–0.0872							
NP	0.5685	0.0689	0.162	–0.2457	0.0713	0.5912						
PH	0.6121	0.0615	0.3582	–0.479	0.346	0.503	0.4762					
SD	0.0799	0.0605	0.0173	–0.0639	0.019	0.0561	–0.2269	–0.1152				
NL	0.352	0.075	0.4088	–0.5501	0.2064	0.2889	0.0939	0.4945	0.3585			
ALS	0.1621	0.3717	–0.0922	–0.1515	0.1053	0.1068	0.056	0.2428	0.2346	0.1578		
PS	0.223	0.1951	–0.1706	0.0690	0.2333	0.0996	0.1954	0.2491	0.1096	0.0321	0.3567	

DMP - dry matter production (kg/ha); LB - leaf blade; PAN - panicle; DM - dry matter content; FMP - fresh matter production (kg/ha); TD - tiller density; PH - plant height, SD - stem diameter, NL - number of green leaves per tiller; ALS - average leaf size; PS - panicle size.

The correlation coefficient for plant height and percentage of leaf blade was r = 0.06, results confirmed by Neumann et al. (2002a), who did not find associative relationship between plant height and leaf mass in different sorghum hybrids. For DMP, the correlation with percentage of leaf blade was close to neutral, with r = 0.0407.

Leaves and panicles are the plant components of highest digestibility coefficient and, in theory, highest overall digestibility (Zago, 1992; Flaresso et al., 2000). Therefore, these are key variables in the selection of genetic materials with suitable properties for silage quality.

Thus, due to the positive correlation of agronomic characteristics with DMP and to avoid associative effects, plant height, tiller density, and FMP were not included as part of the discriminatory variables of the clustering.

The agronomic characteristics DMP and percentage of panicle and leaves were used as discriminatory variables, resulting in the dissimilarity dendrogram (Figure 1).

A cut was subjectively made in the dendrogram according to Johnson & Wichern (1992), considering 20% of dissimilarity, resulting in the hierarchical establishment of five groups. Two groups were formed with nine and five cultivars and another three groups were formed with eight, five, and five cultivars. The groups are in a mean Euclidean distance lower than 3.72 compared with the cultivars. Still, it was observed that there was variability within groups, which may indicate that within them, some cultivars can be highlighted for the agronomic characteristics.

Group 1 was formed by cultivars 1, 21, 20, 28, 27, 30, 2, 14, and 25, in a total of nine cultivars; group 2 was composed of cultivars 4, 24, 29, 23 and 32, with five cultivars; group 3 was formed by cultivars 3, 6, 5, 31, 12, 7, 13 and 16, totaling eight cultivars; group 4 was

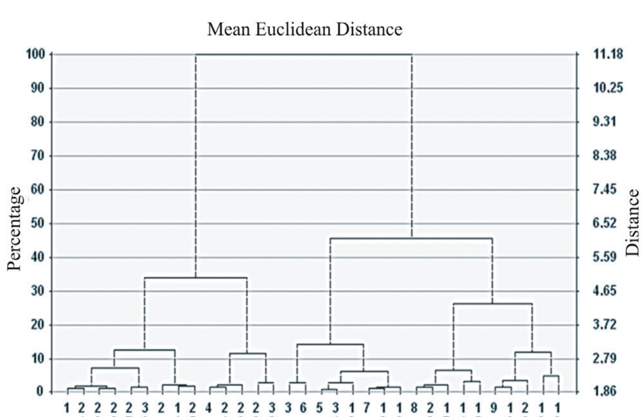

Figure 1 - Dissimilarity dendrogram of agronomic characteristics of 32 sorghum cultivars.

formed by the cultivars 8, 22, 17, 11, and 15, amounting to five cultivars; and group 5 was formed by cultivars 9, 19, 26, 10, and 18, in a total of five cultivars.

The percentages of the components leaf, stem, and panicle varied according to the groups formed (Table 3). For the variable leaf blade, the mean values of the groups ranged between 9.01 and 14.83%. Groups 4 and 5 had higher mean values: 14.83 and 13.65%, respectively.

The percentage of stem had high values for all groups, probably influenced by plant height. There was variation in the average values of stem, ranging from 74.98 to 84.00%, given that the maximum values of groups 3 and 4 were 87.63 and 85.35%, respectively. Groups 2 and 5 were those which had the lowest mean values, which were lower than 76% of the stem component.

As for the percentage of panicle, group 2 had the highest mean value, 15.79%, followed by group 5 with 11.36% of panicle. The other groups had values between five and 7% of panicle.

These results for percentage of plant components showed a forage characteristic of the sorghum, whereas low values of panicle and high values of stem were influenced by the plant height. The elevated height is a desirable characteristic for the interest of sorghum production, but the plant height is positively correlated with the percentage of stem, which is the main responsible for production of silage of lower nutritional value due to its low nutritional quality (Flaresso et al., 2000).

The contents of dry matter varied according to the groups, from 23.56 to 30.09%. According to McDonald et al. (1991), the dry matter content is considered appropriate when above 25%. In the present study only group 1 showed inappropriate values, the others having values above that recommended by the author.

The low dry matter content of the plant can be explained by the high proportion of stem, which has the highest level of moisture in the plant (Neumann et al., 2002a). The presence of panicles may be responsible for the increase in the DM content of the ensiled material, as the panicle has lower water content (Zago, 1991). The present study identified no correlation between the percentage of panicle and dry matter content (r = 0.05) (Table 3), probably because forage sorghum has a low percentage of panicle, so it cannot reduce the plant moisture.

For variable FMP, groups 3 and 4 had higher means, of 66,968.16 and 60,492.28 kg ha^{-1}, respectively. The means ranged between 43,053.34 and 66,968.16 kg ha^{-1}, in which groups 1 and 5 showed intermediate mean values, between 53,903.52 and 50,831.79 kg h^{-1}, with group 2 having the lowest mean value.

Regarding DMP, it was observed that groups 1 and 2 were the groups formed by the least productive genotypes, averaging 12,597.65 and 10,826.36 kg ha^{-1}. On the other hand, groups 3, 4 and 5 were formed by the most productive genotypes, with mean values of 18,604.50, 17,223.17 and 15,037.63 kg ha^{-1}. Cunha & Lima (2010), evaluating genotypes of sorghum from IPA/PE, found DMP ranging from 8,000 to 26,000 kg ha^{-1}, with a mean of 15,703 kg ha^{-1} with an average monthly precipitation of 170.2 mm during the studied period. Evaluating five sorghum cultivars in the same area as the present study, Perazzo et al. (2013) observed DMP of 12,073.55 kg ha^{-1}, with 115 mm of rain.

Among the discriminatory variables, DMP was able to gather more uniform groups and this reflected in the coefficient of variation (CV) of this variable. Nevertheless, this was not true for the panicle variable, and this can be observed in group 4, with a CV of 42.9%, so this group had a genotype with values ranging between 7.73 and 2.48%.

It was not possible to find groups with higher panicle and DMP values simultaneously, but the behavior of group 5 was noteworthy, as it gathered considerable values for both variables, averaging 15,037.63 kg ha^{-1} of DMP and 11.36% of panicle, besides 13.65% of leaf. Group 1 had lower means for DMP and percentage of panicle compared with the other groups.

The tiller density variable followed similar orders to DMP according to the groups, due to the associative effect. More productive groups showed higher tiller density, such as group 3, 4 and 5, which obtained 175,629.08, 164,479.93 and 156,807.40 plants/ha, respectively.

For plant height, groups 3 and 4 had mean values around 4.0 m, with low variation within groups (CV = 4.87 and 3.51%, respectively). However, groups 1 and 2 had mean values near 3.0 m and group 5 showed an intermediate height (3.58 m) compared with the others. The values for plant height in the present study are higher than those found by Monteiro et al. (2004), in which the highest mean height was 2.98 m for genotype VSF-T when evaluating the performance of forage sorghum genotypes in the semi-arid region of Pernambuco State (Brazil).

For stem diameter, a wide variation was found in the groups, with emphasis on group 2 (CV = 28.42). Group 4 showed a greater mean diameter, 1.98 cm, obtaining maximum value of 2.30, while group 2 had the lowest mean value among the groups, 1.59 cm.

Group 4 showed the greatest average leaf size, and group 2 had the lowest value for this variable. These results influence the participation of the leaf in the sorghum, which showed similar figures. This correlation between the two variables are confirmed by Table 2, where r = 0.3717. The same was not true for the variable number of green leaves per tiller, which showed no associative effect with the percentage of plant leaf (r = 0.075). Groups 3 and 4 had 11 leaves; group 1 and 5 had ten leaves, and group 2 had eight leaves, close to mean values.

Table 3 - Descriptive statistics of the agronomic characteristics of the groups formed by 32 sorghum cultivars

Groups		Variables											
		LB	Stem	PAN	DM	FMP	DMP	TD	PH	SD	ALS	PS	NL
		%				kg ha^{-1}		tiller ha^{-1}	m	cm			
1	Mean	10.05	82.50	7.43	23.56	53,903.52	12,597.65	144,392.81	3.07	1.86	68.55	28.94	10.00
	Maximum	11.36	86.82	10.14	27.19	68,112.97	14,973.02	172,632.00	3.72	2.26	77.27	33.33	12.00
	Miminum	8.25	79.29	4.75	19.38	37,065.35	8,976.89	74,327.66	1.90	1.58	59.93	23.66	8.33
	CV	11.28	3.44	26.11	9.75	17.44	14.97	23.75	21.05	13.69	10.10	13.94	13.41
2	Mean	9.01	75.19	15.79	25.32	43,053.34	10,826.36	136,667.00	2.85	1.59	64.19	28.70	8.60
	Maximum	11.98	81.67	21.39	27.00	49,520.36	12,000.76	194,211.00	3.94	2.22	75.19	34.50	11.50
	Miminum	7.07	66.62	10.87	23.89	37,089.32	8828.39	79,123.00	1.76	1.00	52.75	15.33	7.00
	CV	22.74	8.21	26.67	5.04	10.29	11.19	36.14	28.34	28.42	15.71	27.25	20.89
3	Mean	10.45	84.00	5.53	28.02	66,968.16	18,604.50	175,629.08	3.97	1.83	71.17	32.97	11.06
	Maximum	13.62	87.63	7.47	32.27	73,747.10	22,943.26	213,392.33	4.16	2.03	82.19	39.66	11.50
	Miminum	8.08	79.72	4.28	24.09	57,444.10	15,852.82	153,450.66	3.59	1.25	62.38	29.00	10.50
	CV	16.98	3.18	19.65	11.37	10.41	13.68	11.32	4.87	13.48	9.43	11.23	2.89
4	Mean	14.83	80.13	5.02	28.43	60,492.28	17,223.17	164,479.93	4.01	1.98	78.73	31.63	11.06
	Maximum	16.94	85.35	7.73	31.95	63,006.30	18,870.63	184,620.33	4.15	2.30	88.41	33.16	11.66
	Miminum	12.15	75.31	2.48	26.34	55,974.43	15,474.34	143,860.00	3.83	1.71	61.72	28.00	10.66
	CV	11.74	4.67	42.95	7.71	4.81	7.70	10.54	3.51	10.66	13.33	6.65	3.92
5	Mean	13.65	74.98	11.36	30.09	50,831.79	15,037.63	156,807.40	3.58	1.76	72.40	31.76	10.16
	Maximum	18.30	76.98	12.95	33.25	61,543.82	17,751.99	201,404.00	4.16	2.15	79.30	40.50	10.66
	Miminum	10.32	73.21	6.79	26.53	34,979.52	11,084.42	129,474.00	2.91	1.43	64.66	23.83	8.66
	CV	23.62	2.31	22.76	9.12	21.77	17.03	17.91	12.87	14.58	7.93	19.68	8.51

LB - leaf blade; PAN - panicle; DM - dry matter t; FMP - fresh matter production; DMP - dry matter production; TD - tiller density; PH - plant height; SD - stem diameter; ASL - average leaf size; PS - panicle size; NL - number of green leaves per tiller; CV - coefficient of variation.

For panicle size, groups 3, 4 and 5 showed mean values above 30.0 cm, and the other groups had mean values around 28.0 cm. These values are not correlated with the percentage of plant panicle (r = 0.069), but forage sorghum does not have a developed panicle, and this may be a factor to be considered.

Conclusions

Groups 3, 4 and 5 show high potential of dry matter production, especially group 5, which gathers considerable levels for characteristics of production, percentage of panicle and leaf.

The presence of evident variation among cultivars, mainly for the production of dry matter, allows for a selection of cultivars that are more productive and thus more suitable for silage production in semi-arid regions.

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