Revista Brasileira de Milho e Sorgo

Brazilian Journal of Maize and Sorghum

ISSN 1980 - 6477

Journal homepage: www.abms.org.br/site/paginas

AGRONOMIC TRAITS EVALUATION IN IRRIGATED SORGHUM IN THE BRAZILIAN SEMI-ARID

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Abstract – Green and dry matter production, along with grain yield and other agronomic traits, were assessed in 44 sorghum genotypes. Two sets of genotypes were formed based on known plant height, aiming to evaluate green and dry matter production and grain yield, as well as to separate forage and grain sorghum genotypes. The evaluations were performed based on experiments with three replications, being one irrigated (drip system) in Petrolina, State of Pernambuco, and the other rainfed, in Nossa Senhora da Glória, state of Sergipe, Brazil. Sowing dates were July 30, 2016, in Nossa Senhora da Glória; July 13, 2017, and October 24, 2018, in Petrolina; with 117 and 128 days from sowing to harvest, respectively. Expressive forage production was observed in genotypes EP-17 and SF-11, which exceeded 120 t ha^{-1}. BRS 506 produced 108 t ha^{-1}, while 13F03(1141572), P-294, P-288, 2502 x 467, BRS Ponta Negra, and SF-15 presented green matter production ranging from 94 to 98.5 t ha^{-1}. Dry matter production was highly correlated with green matter production, and SF-11 had the best performance of 45.5 t ha^{-1}. The observed plant height was more expressive for forage sorghum genotypes, being this trait highly correlated with the green and dry matter. The best grain yield performance reached 13.4 and 10.3 t ha^{-1}, values observed for 9910032 and BRS Ponta Negra, respectively. The results demonstrate the full adaptability of sorghum to the semi-arid environment and the feasibility to produce roughage and grains under irrigation in the Brazilian semi-arid region.

Keywords: *Sorghum bicolor*, roughage, forage, grain yield, caatinga.

AVALIAÇÃO DE CARACTERÍSTICAS AGRONÔMICAS DE SORGO IRRIGADO NO SEMIÁRIDO BRASILEIRO

Resumo - A produção de matéria verde e seca juntamente com a produção de grãos e outros caracteres agronômicos foram avaliados de 44 genótipos de sorgo. Dois conjuntos de genótipos foram formados com base na altura de planta conhecida, com o objetivo de avaliar a produção de grãos e de biomassa verde e seca além de separar materiais forrageiros de graníferos. Avaliações foram feitas em experimentos com três repetições com irrigação por gotejamento em Petrolina, PE e dependente de chuva em Nossa Senhora da Glória, SE. Em Nossa Senhora da Glória o plantio ocorreu em 30 de julho de 2016, e em Petrolina, em 13 de julho de 2017 e 24 de outubro de 2018, com 117 e 128 dias de ciclo, respectivamente. Expressiva produção de forragem foi observada, superior à 120 t ha^{-1} no genótipo EP-17 e SF-11, enquanto BRS 506 produziu 108 t ha^{-1} e 13F03(1141572), P-294, P-288, 2502 x 467, BRS Ponta Negra e SF-15 produziram matéria verde no intervalo entre 94 e 98,5 t ha^{-1}. A produção de matéria seca foi altamente correlacionada com a produção de matéria verde e a melhor performance foi 45,5 t ha^{-1} para SF-11. A altura de plantas observada foi mais expressiva para os tipos forrageiros e esse caráter foi altamente correlacionado com matéria verde e seca. A melhor performance em produção de grãos alcançou 13,4 e 10,3 t ha^{-1}, sendo observada em 9910032 e BRS Ponta Negra, nessa ordem. Os resultados obtidos demonstram a total adaptação do sorgo ao ambiente semiárido e a viabilidade de produzir volumoso e grãos sob irrigação no semiárido brasileiro.

Palavras-chave: *Sorghum bicolor*, volumoso, forragem, produção de grãos, caatinga.

How to cite

REGITANO NETO, A.; SANTOS, R. D. Agronomic traits evaluation in irrigated sorghum in the brazilian semi-arid. **Revista Brasileira de Milho e Sorgo**, v. 19, e1179, 2020.

DOI: https://doi.org/10.18512/rbms2020v19e1179

Animal farming in semi-arid environment is usually associated with uncertainties regarding water availability for animals and crops. In Brazil, the caatinga environment comprises around 980 thousand square kilometers and is one of the most populated dry areas in the world, being a home to more than 22 million people, although having to live with low socioeconomic indices (Silva et al., 2010).

Livestock farming has been the main activity for most farmers in the caatinga, and a large amount of sheep (12.6 million) and goats (10.0 million) are been reared in the 9 states of the northeastern part of Brazil. Moreover, 27.8 million bovine animals are raised in this environment, distributed over less dry areas, aimed at dairy farming (IBGE, 2019).

Forage production is a difficult task in the semi-arid climate and irrigation plays a major role in enabling crop production under such a restrictive environmental condition.

Sorghum (*Sorghum bicolor* L. Moench), along with other forage grasses, is a highly promising crop for animal feeding, and produces a large amount of high quality green forage that can be either served chopped to animals or stored, preserved in form of silage, which represents a very feasible strategy for animal consumption during warmer and drier months.

With origins dating back 5 or 6 thousand years, where we can find Sudan and Ethiopia in the African continent (Santos et al., 2005), sorghum accumulated, through generations of natural selection, characteristics to grow and produce seeds under that sub-Saharan environment. Such drought resistance traits include C4 photosynthetic pathway, usual in plants from hot and arid places subject to drought; stomates on both sides of the leaves; ability to roll the leaves lengthwise creating a more secure microenvironment to open the stomates; and a wax deposition in the foliar limbus – leaf sheath junction (Magalhães et al., 2003).

Sorghum producers can find several hundreds of registered sorghum cultivars in the Brazilian seed market, most of them developed for grain production, though forage and double purpose (grain / forage) cultivars are also available and of major interest for northeastern livestock producers.

This report presents green and dry matter yield and other biometric data for 44 sorghum genotypes cultivated under drip irrigation, in the caatinga environment of the São Francisco River Valley in Petrolina, state of Pernambuco, and under rainfed conditions, in the agreste environment of Nossa Senhora da Glória, state of Sergipe, Brazil.

Material and Methods

Performance analyses took place at the Experimental Field of Nossa Senhora da Glória (C.E.G.), state of Sergipe, in 2016 (Environment 1), and the Experimental Field of Bebedouro (C.E.B.), from Embrapa Semi-Arid in Petrolina, state of Pernambuco, in 2017 (Environment 2) and 2018 (Environment 3), all in the northeast region of Brazil. A randomized block design was used for the experiment, with 3 replications. The experimental plots consisted of 4 rows of 5 meters, spaced 0.8 m apart, with 15 plants m^{-1}. Drip irrigation was available and water was applied as needed. For measurements, only the two central rows were considered as useful area, discarding 0.5 m from each end. Fertilizer was applied based on soil analysis, and before the 2017 and the 2018 crops at C.E.B. The analysis revealed the following characteristics: pH= 6.10; P= 28.43 mg dm^{-3}; K= 0.38 $cmol_c$ dm^{-3}; Al= 0.10 $cmol_c$ dm^{-3}; H + Al= 1.71 $cmol_c$ dm^{-3}; Ca= 1.70 $cmol_c$ dm^{-3}; Mg= 2.00 $cmol_c$ dm^{-3}; C= 0.00 g kg^{-1}; V= 71.0%, which determined sowing fertilization with 300 kg ha^{-1} of the 6-24-12 formula and top dressing with 70 kg ha^{-1} of nitrogen, divided in three applications at 15, 30 and 45 days after emergence. Sowing dates were July 30, 2016 for Environment 1; July 13, 2017 for Environment 2; and October 24, 2018 for Environment 3. Harvest occurred at 117 days for Environment 2 and 128 days for Environment 3.

The evaluated genotypes are listed in Table 1 and comprised commercial cultivars from the seed market, experimental populations derived from institutional breeding programs (Embrapa and IPA - Agricultural and Livestock Research Enterprise of the State of Pernambuco), and accessions from the sorghum germplasm bank of Embrapa Maize and Sorghum. The genotypes were divided into two groups, based on the known plant height. In Experiment 1, taller plants were included, indicating types of cultivars for forage production, while Experiment 2 comprised the shorter plants, with assumed grain production ability. Evaluation was carried out for each genotype group formed in an individual experiment, with 6 common genotypes, identified in Table 1, used as checks.

Evaluations were performed and biometric data were taken from the essays. Information of flowering (FLO, days), plant height (PH, m) and panicle length (PL, cm) were collected in Environment 1; flowering, plant height, green matter yield (GM, t ha^{-1}), dry matter yield (DM, t ha^{-1}), grain yield (GY, kg ha^{-1}) and seed mass (SM, mg) in Environment 2; and plant height and green matter yield in Environment 3.

Simple and joint analysis of variance (ANOVA) were performed, and Scott-Knott mean test ($p<0.05$) was used to rank the results. Pearson's correlation coefficients were estimated between the traits.

Results and Discussion

The variability observed among sorghum genotypes in the experiments was very wide. Even considering one experiment at a time, a large variation could be observed for matter production (green or dry) and plant architecture.

From the experiments with forage plants (Table 2), the most expressive GM production exceeded 120 t ha^{-1} for genotypes EP-17 and SF-11. BRS 506 produced 108 t ha^{-1}, while 13F03(1141572), P-294, P-288, 2502 x 467, BRS Ponta Negra and SF-15 were in the range

DOI: https://doi.org/10.18512/rbms2020v19e1179

Table 1. Sorghum genotypes evaluated in Petrolina, PE, and in Nossa Senhora da Glória, SE.

Number (#)	Genotypes (G)	Experiment (E)	Institution
1	BRS 506	1	Embrapa
2	13F03(1141562)	1	Embrapa
3	13F03(1141572)	1	Embrapa
4	947216	1	Embrapa
5	13F02(1141570)	1	Embrapa
6	9929030	1	Embrapa
7	947030	1	Embrapa
8	947254	1	Embrapa
9	SS318	1	Embrapa
10	ICSV745	1	Embrapa
11	IPA 2502	1	IPA
12	EP-17	1	IPA
13	SF-11	1	IPA
14	P-294	1	IPA
15	P-288	1	IPA
16	BRS 506 X 2506	1	IPA
17	2502 X 467	1	IPA
18	Theis X 2501	1	IPA
19	IPA 2564	1	IPA
20	Sureno 160.0	2	Embrapa
21	ICSV400	2	Embrapa
22	EBA-3	2	Embrapa
23	SC971	2	Embrapa
24	FC13642 Pink Kafir (ASA Nº22)	2	Embrapa
25	Marupantse	2	Embrapa
26	PI48770 White Kafir (ASA Nº21)	2	Embrapa
27	M35-1	2	Embrapa
28	SC224	2	Embrapa
29	SC1337	2	Embrapa
30	SC323	2	Embrapa
31	Segaolane	2	Embrapa
32	Sureno 167.5	2	Embrapa
33	CMSXS189	2	Embrapa
34	SC720	2	Embrapa
35	9910032	2	Embrapa
36	Pinolero 1	2	Embrapa
37	Jocoro	2	Embrapa
38	Kuyuma	2	Embrapa
39	SF-15	check	IPA
40	BRS Ponta Negra	check	Embrapa
41	BRS 655	check	Embrapa
42	Volumax	check	Monsanto
43	BRS 658	check	Embrapa
44	BRS 659	check	Embrapa

Table 2. Means of green matter and plant height for 25 forage sorghum genotypes (E1) evaluated in Petrolina, PE (C.E.B) and in Nossa Senhora da Glória, SE (C.E.G.).

Genotypes	Green Matter (t ha^{-1})*				Plant Height (m)					
	C.E.B. 2017		C.E.B 2018		C.E.B. 2017		C.E.B 2018		C.E.G 2016	
BRS 506	108.1	Aa	59.6	Bb	2.22	Bb	2.03	Bb	2.76	Aa
13F03(1141562)	94.0	Aa	85.4	Aa	1.83	Bc	3.08	Aa	2.41	Ba
13F03(1141572)	56.2	Ab	76.2	Aa	1.47	Bc	2.25	Ab	2.57	Aa
947216	76,2	Ab	62.3	Ab	1.49	Bc	1.99	Bb	2.56	Aa
13F02(1141570)	88.5	Aa	80.8	Aa	2.26	Ab	2.92	Aa	2.35	Aa
9929030	65.9	Ab	54.8	Ab	1.09	Bc	1.69	Ab	1.93	Aa
947030	58.0	Ab	49.5	Ab	1.57	Bc	1.73	Bb	3.06	Aa
947254	63.2	Ab	51.5	Ab	1.63	Ac	2.17	Ab	2.28	Aa
SS318	73.3	Ab	63.7	Ab	1.62	Bc	2.17	Ab	2.43	Aa
ICSV745	61.3	Ab	62.1	Ab	1.89	Bc	2.59	Aa	2.85	Aa
IPA 2502	38.2	Bb	46.7	Ab	1.36	Ac	1.70	Ab	2.10	Aa
EP-17	121.8	Aa	97.3	Aa	2.90	Aa	3.05	Aa	2.53	Aa
SF-11	120.1	Aa	101.2	Aa	2.69	Aa	2.55	Aa	2.30	Aa
P-294	97.5	Aa	59.2	Bb	2.24	Ab	2.33	Ab	2.13	Aa
P-288	96.9	Aa	62.4	Bb	1.87	Bc	1.97	Bb	2.57	Aa
BRS 506 X 2506	76.6	Ab	63.3	Ab	2.11	Ab	2.35	Ab	2.37	Aa
2502 X 467	98.5	Aa	65.2	Bb	2.26	Ab	2.13	Ab	2.39	Aa
Theis X 2501	67.2	Ab	42.1	Ab	1.75	Bc	2.17	Bb	2.69	Aa
IPA 2564	70.0	Ab	79.6	Aa	1.28	Bc	2.08	Ab	2.66	Aa
BRS Ponta Negra	94.1	Aa	79.8	Aa	2.16	Ab	2.30	Ab	2.49	Aa
BRS 655	64.1	Ab	69.6	Ab	1.38	Bc	2.16	Ab	2.42	Aa
Volumax	83.6	Aa	80.8	Aa	1.51	Bc	2.25	Ab	2.56	Aa
BRS 658	58.5	Ab	74.1	Aa	1.60	Ac	2.25	Ab	2.21	Aa
BRS 659	81.0	Ab	68.5	Ab	1.58	Ac	2.15	Ab	2.18	Aa
SF-15	95.9	Aa	84.0	Aa	2.69	Aa	2.82	Aa	2.94	Aa
Means	80.3		68.8		1.86		2.27		2.47	
CV%	18.6		22.31		7.42		13.72		22.87	

*Means in columns followed by the same lowercase letters are not significantly different; means in rows, within traits, followed by the same uppercase letter are not significantly different according to Scott-Knott mean test at $p<0.05$.

of 94 to 98.5 t of GM per hectare. Among grain sorghum genotypes (Table 3), GM mean values showed much less expressive production, but since the experiment comprised a heterogeneous group of genotypes, the mean GM yield varied from 65.3 t ha^{-1} in SC971 to 27.6 t ha^{-1} in ICSV400. As reported by Santos et al. (2013), GM yield with no irrigation was 89.4 t ha^{-1} (BRS 506), 76.2 t ha^{-1} (BRS Ponta Negra), and 68.0 (BRS 601) t ha^{-1}, while GM yield presented by Perazzo et al. (2013) was 52.1 t ha^{-1} (BRS Ponta Negra), 43.6 t ha^{-1} (IPA 1011), and 42.7 t ha^{-1} (SF 15).

DOI: https://doi.org/10.18512/rbms2020v19e1179

Table 3. Means of green matter and plant height for 25 grain sorghum genotypes (E2) evaluated in Petrolina, PE (C.E.B) and in Nossa Senhora da Glória, SE (C.E.G.).

Genotypes	Green Matter (t ha^{-1})*				Plant Height (m)					
	C.E.B. 2017		C.E.B 2018		C.E.B. 2017		C.E.B 2018		C.E.G. 2017	
Sureno 160.0	48.1	Ab	35.6	Ab	1.48	Bc	1.71	Bb	2.20	Aa
ICSV400	27.6	Ac	46.8	Aa	1.44	Bc	1.59	Bc	2.13	Aa
EBA-3	27.6	Ac	19.7	Ab	1.36	Bc	1.79	Bb	2.26	Aa
SC971	65.2	Ab	31.0	Bb	1.49	Ac	1.49	Ac	1.66	Ab
FC13642 Pink Kafir	47.1	Ab	27.9	Ab	1.38	Bc	1.36	Bc	2.43	Aa
Marupantse	49.6	Ab	28.1	Ab	1.54	Ac	1.46	Ac	1.86	Ab
PI48770 White Kafir	42.2	Ab	30.6	Ab	1.25	Bc	1.41	Bc	1.83	Ab
M35-1	53.4	Ab	14.6	Bb	2.02	Ab	1.85	Ab	1.81	Ab
SC224	48.9	Ab	36.2	Ab	1.71	Ac	1.61	Ac	1.80	Ab
SC1337	59.0	Ab	20.1	Bb	1.29	Bc	1.35	Bc	2.05	Aa
SC323	44.2	Ab	30.6	Ab	1.32	Bc	1.58	Bc	2.24	Aa
Segaolane	55.4	Ab	29.0	Bb	1.32	Bc	1.44	Bc	2.00	Ab
Sureno 167.5	43.5	Ab	34.7	Ab	1.45	Ac	1.95	Ab	1.82	Ab
CMSXS189	64.7	Ab	63.3	Aa	1.44	Bc	2.04	Ab	1.83	Ab
SC720	45.2	Ab	30.4	Ab	1.06	Bc	1.33	Bc	1.88	Ab
9910032	59.4	Ab	26.8	Bb	1.19	Bc	1.07	Bc	2.15	Aa
Pinolero 1	52.7	Ab	17.9	Bb	1.29	Bc	1.23	Bc	1.83	Ab
Jocoro	29.7	Ac	31.7	Ab	1.12	Bc	1.38	Bc	1.76	Ab
Kuyuma	30.1	Bc	62.2	Aa	1.10	Bc	1.31	Bc	2.13	Aa
BRS Ponta Negra	95.7	Aa	69.6	Ba	2.14	Ab	2.13	Ab	2.20	Aa
BRS 655	83.8	Aa	61.2	Aa	1.41	Bc	1.87	Ab	2.32	Aa
Volumax	78.7	Aa	49.0	Ba	1.56	Ac	1.82	Ab	1.89	Ab
BRS 658	65.3	Ab	64.4	Aa	1.64	Ac	1.89	Ab	1.94	Ab
BRS 659	57.4	Ab	47.5	Aa	1.59	Ac	1.81	Ab	1.91	Ab
SF-15	102.9	Aa	87.8	Aa	3.00	Aa	2.85	Aa	2.04	Ba
Means	55.1		39.9		1.50		1.65		2.00	
CV%	26.40		36.61		8.96		12.02		20.24	

** Means in columns followed by the same lowercase letters are not significantly different; means in rows, within traits, followed by the same uppercase letter are not significantly different according to Scott-Knott mean test at $p<0.05$.

The obtained results can be compared with those reported by Pimentel et al. (2017), when testing biomass sorghum BD 7607 and BRS 716, which produced 110 and 108 t ha^{-1} of GM, corresponding to DM yield of 43 and 41 t ha^{-1}, respectively, in a five-month period. Since livestock production is an important activity for northeastern farmers, the results of GM presented in Table 2 and 3 provide important information regarding the potential for forage production under irrigation of experimental and commercial sorghum genotypes.

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ANOVA for GM from experiment 1 and 2 (Table 4) showed the magnitude of the variation for this trait with highly significant mean squares (MS) for genotypes (G) and environments (E). Although the G x E interaction had no significant MS in experiment 1 (forage sorghum genotypes), it was highly significant in experiment 2 (grain sorghum genotypes). Ferrari Júnior et al. (2005) emphasize the importance of taking GM estimates as a key parameter for dimensioning of silos, aiming at silage production.

Plant height (PH) means are presented in Tables 2 and 3 and show taller plants in experiment 1, with overall mean of 2.20 m, while in experiment 2, they had mean value of 1.72 m. The estimated coefficients of correlation (Table 5) between PH x GM and PH x DM were highly significant, with values of 84.84% and 57.25%, respectively, thus showing that GM and DM yield are directly and positively influenced by PH and determine the architecture of forage and grain sorghum cultivars.

The PH reported by Oliveira et al. (2018) for rainfed sorghum cultivated in Nossa Senhora da Glória, SE, was 3.0 m for SF-15, BRS 601 and BRS 506; 2.5 m for BRS 655; and 1.9 m for IPA 2502. Still in regard to rainfed sorghum, Santos et al. (2013) reported PH for BRS 506 (2.6 m), BRS 601 (2.5 m), BRS Ponta Negra (2.3 m), BRS 610 (2.10 m) and BRS 655 (1.9 m), and presented correlation coefficient of 89 and 78% between PH x GM and PH x DM, respectively. Highly correlated with forage yield (GM and DM), the PH of irrigated sorghum plants, in this experiment, showed more expressive magnitudes than of those not irrigated. Among the experiments, the most expressive PH was noticed in 2018, for genotypes 13F03(1141562) and EB 17, with values of 3.08 and 3.05 m, respectively. The joint ANOVA for PH (Table 4)

Table 4. Mean squares (MS), significances and p-values from joint ANOVA of forage (E1) and grain (E2) sorghum experiments, for green matter (GM) and for plant height (PH) from two and three locations, respectively.

Sources	Green Matter					Plant Height				
	E1			E2		E1			E2	
	df	MS. 10^6	*p*	MS. 10^6	*p*	df	MS	*p*	MS	*p*
Genotypes	24	1574.66	0.0 **	1758.66	0.0 **	24	0.760	0.0 **	0.597	0.0 **
Environments	1	5006.30	0.0 **	8702.91	0.0 **	2	7.332	0.0 **	4.836	0.0 **
G x E	24	415.63	0.07^{ns}	437.25	0,01**	48	0.280	0.0**	0.210	0.0 **
Error	98	269.46		215.10		148	0.151		0.076	
Mean		74.6 t ha^{-1}		47.5 t ha^{-1}			2.20 m		1.72 m	
CV%		22.02		30.89			17.67		16.02	

** *: Significant at 1% and 5% probability, respectively, according to F-test.

Table 5. Mean Pearson's correlation coefficients between studied variables, respective significance, and *p*-value.

	GM	PH	DM	GY	SM	PL
PH	0.8484** 0.00					
DM	0.6829** 0.00	0.5725** 0.00				
GY	0.0504^{ns} 0.73	0.0340^{ns} 0.81	-0.2093 ^{ns} 0.14			
SM	-0.3714** 0.01	-0.2648^{ns} 0.06	-0.3962** 0,00	0.2631 ^{ns} 0.06		
PL	0.3645** 0.01	0.2076^{ns} 0.14	0.4530** 0.00	-0.0835^{ns} 0.57	-0.2966* 0.03	
FLO	0.1747^{ns} 0.22	0.1825^{ns} 0.20	0.3261* 0.02	0.2285^{ns} 0.11	-0.3269* 0.02	0.4654** 0.00

** *: Significant at 1% and 5% probability, respectively, according to t-test.

showed highly significant MS for all sources of variation in both experiments, indicating large variation for this trait, due to the remarkably diverse group of genotypes assessed and different environments.

Mean values for DM, GY and SM were evaluated in 2017 (Tables 6 and 7). Data from DM demonstrated the potential of the forage sorghum genotypes to produce roughage, under drip-irrigation, for ruminant's consumption in the caatinga environment. DM means were highly correlated with GM means (68.29%) (Table 7) and expressive performance was noted for SF-11 and 13F03(1141562), with values of 45.48 and 39.18 t ha^{-1}, respectively. Santos et al. (2013) reported DM yield ranging from 25.2 t ha^{-1} for BRS 506 to 17.1 t ha^{-1} for BRS 655, with no irrigation. On the other hand, GY, assessed through panicle protection (screen bag) to prevent bird damage, showed expressive grain production in experiment 2, reaching 13.39 and 10.28 t ha^{-1} in genotypes 9910032 and BRS Ponta Negra, respectively. Grain yield of such magnitude in that semi-arid environment can be attributed to the C4 photosynthesis pathway of sorghum plants combined with an abundance of solar radiation characteristic of the low latitude of the region where the experimental field is located, in addition to the good soil fertility in the area and full ET replacement irrigation. Zwirtes et al. (2015) observed GY of 6.28 t ha^{-1} in Santa Maria, RS, while Farre and Faci (2006) reported GY of 8.54 t ha^{-1} in Spain, both with replacement of 100% of ETc. Araya et al. (2018) observed GY for irrigated sorghum in Kansas, USA, of 7.7, 8.4 and 9.3 t ha^{-1} in the years of 2008, 2009 and 2012, respectively.

The ANOVA for DM and GY data is presented in Table 8 and Table 9, and showed large variation among the genotypes in both

Table 6. Means for dry matter, grain yield, seed mass, panicle length and days to flowering of 25 forage sorghum genotypes (E1) evaluated in Petrolina, PE and Nossa Senhora da Glória, SE.

Genotypes	Dry Matter ($t\ ha^{-1}$)		Grain Yield ($kg\ ha^{-1}$)		Seed Mass (mg)		Panicle Length (cm)		Days to Flowering			
	C.E.B. 2017						C.E.G 2016		C.E.B. 2017		C.E.G. 2016	
BRS 506	37.4	a	3,109	c	27.3	c	21.4	c	64	b	64	e
13F03(1141562)	39.1	a	5,768	b	34.0	a	23.5	c	55	d	63	e
13F03(1141572)	17.7	b	4,816	c	36.0	a	26.5	b	54	d	67	d
947216	29.9	b	5,432	b	28.3	c	23.1	c	50	f	53	f
13F02(1141570)	29.0	b	9,464	a	30.3	b	23.9	c	61	c	66	e
9929030	23.0	b	2,008	c	26.0	c	22.9	c	48	f	53	f
947030	22.3	b	3,104	c	30.7	b	23.3	c	51	e	53	f
947254	25.0	b	6,736	b	23.3	d	21.9	c	55	d	63	e
SS318	28.4	b	3,517	c	30.7	b	25.1	c	51	e	54	f
ICSV745	27.2	b	7,504	a	24.7	d	22.8	c	62	c	67	d
BRS Ponta Negra	31.3	a	9,168	a	31.7	b	26.1	b	65	b	71	c
IPA 2502	12.2	b	6,914	b	29.3	c	23.9	c	62	c	63	e
EP-17	37.1	a	4,727	c	20.3	d	33.9	a	70	a	84	a
SF-11	45.5	a	2,801	c	21.3	d	28.5	b	71	a	80	a
P-294	29.4	b	4,712	c	17.3	e	28.7	b	62	c	68	d
P-288	26.2	b	5,512	b	20.3	d	25.9	b	70	a	74	b
BRS 506 X 2506	24.8	b	7,899	a	20.7	d	19.1	c	53	d	53	f
2502 X 467	36.6	a	5,368	b	20.3	d	24.7	c	54	d	58	f
Theis X 2501	27.0	b	2,138	c	27.0	c	23.1	c	48	f	53	f
IPA 2564	23.3	b	6,957	b	29.0	c	20.2	c	54	d	54	f
BRS 655	19.4	b	5,936	b	32.7	b	23.2	c	48	f	53	f
Volumax	34.3	a	2,272	c	34.0	a	25.3	c	51	e	53	f
BRS 658	23.8	b	4,062	c	26.0	c	22.2	c	48	f	53	f
BRS 659	28.8	b	8,013	a	31.3	b	24.6	c	49	f	53	f
SF-15	34.4	a	5,588	b	17.0	e	28.5	b	71	a	81	a
Mean	28.5		5,340		26.8		22.0		57.0		62.	
CV%	20.18		29.26		8.53		11.0		2.65		3.44	

** Means in columns followed by the same lowercase letters are not significantly different according to Scott-Knott mean test at $p<0.05$.

experiments, with highly significant MS for G. Overall means of the experiments for DM and GY corroborates the assumed specialty x architecture correlation in the studied cultivar group. Pearson's correlation coefficients (Table 5), estimated between GM or DM and GY, were 5.0 and -20.93%, respectively, indicating that the genotypes in experiment 1 produced more forage (28.53 $t\ ha^{-1}$) than those in experiment 2 (20.67 $t\ ha^{-1}$) in detriment of GY, and inversely, genotypes

DOI: https://doi.org/10.18512/rbms2020v19e1179

Table 7. Means for dry matter, grain yield, seed mass, panicle length and days to flowering of 25 grain type sorghum genotypes (E2) evaluated in Petrolina, PE and Nossa Senhora da Glória, SE.

Genotypes	Dry Matter ($t\ ha^{-1}$)		Grain Yield ($kg\ ha^{-1}$)		Seed Mass (mg)		Panicle Length (cm)		Days to Flowering			
			C.E.B. 2017				C.E.G 2016		C.E.B. 2017		C.E.G. 2016	
Sureno 160.0	17.3	b	6,427	c	28.0	c	18.87	c	58	c	64	c
ICSV400	9.7	b	9,016	c	37.0	a	23.33	b	60	c	63	c
EBA-3	12.1	b	3,588	d	39.0	a	16.00	d	52	d	54	d
SC971	25.6	a	4,293	d	23.7	c	18.47	c	51	d	56	d
FC13642 Pink Kafir	20.7	b	3,508	d	28.3	c	24.33	b	53	d	53	d
Marupantse	18.2	b	4,247	d	35.3	a	26.47	a	52	d	53	d
PI48770 White Kafir	17.6	b	5,062	d	31.0	b	20.53	b	51	d	53	d
M35-1	21.3	b	5,348	d	36.7	a	14.60	d	61	c	75	a
SC224	18.4	b	2,781	d	17.7	d	25.27	a	49	e	54	d
SC1337	23.1	a	1,585	d	35.3	a	23.40	b	44	e	53	d
SC323	19.0	b	4,396	d	25.3	c	13.33	d	48	e	53	d
Segaolane	22.9	a	4,956	d	31.0	b	22.20	b	48	e	53	d
Sureno 167.5	16.2	b	6,325	c	28.3	c	19.07	c	60	c	63	c
CMSXS189	29.5	a	7,045	c	30.3	b	17.73	c	51	d	53	d
SC720	15.1	b	6,083	d	27.0	c	15.73	d	48	e	54	d
9910032	18.0	b	13,393	a	39.0	a	23.07	b	54	d	64	c
Pinolero 1	16.2	b	7,905	c	35.7	a	22.27	b	58	c	64	c
Jocoro	9.6	b	7,059	c	28.7	c	26.20	a	69	a	63	c
Kuyuma	9.0	b	7,262	c	31.3	b	20.73	b	60	c	65	c
BRS Ponta Negra	31.6	a	10,285	b	33.0	b	23.80	b	65	b	70	b
BRS 655	27.8	a	5,631	d	28.7	c	22.80	b	49	e	53	d
Volumax	32.4	a	5,314	d	36.7	a	24.87	a	54	d	53	d
BRS 658	24.3	a	6,692	c	28.7	c	22.93	b	50	e	53	d
BRS 659	21.6	b	7,345	c	31.7	b	23.47	b	50	d	53	d
SF-15	39.6	a	4,147	d	19.0	d	28.60	a	72	a	77	a
Mean	20.7		5,987		30.6		24.00		54.7		58.8	
CV%	36.33		28.60		10.97		7.93		4.07		2.99	

** Means in columns followed by the same lowercase letters are not significantly different according to Scott-Knott mean test at $p<0.05$

in experiment 2 were more efficient as to GY (5.99 $t\ ha^{-1}$) than in experiment 1 (5.34 $t\ ha^{-1}$), regardless of the forage production.

The SM, PL, and FLO traits (Table 6 and 7) demonstrate the large variation among the studied sorghum genotypes. The mass of one sorghum seed ranged from 17 to 36 mg and from 17.7 to 39 mg in experiment 1 and 2, respectively. Bell et al. (2018) reported SM ranging from 25.4 to 27.9 mg, with no correlation being reported between SM and GY, under full irrigation system. The sorghum inflorescence length was measured at harvest and varied from 19.07 to 33.93 cm and from 14.60 to 26.47 cm in experiment 1 and 2, respectively. The genotype cycle was assessed through the number of days taken to reach 50% flowering, with data collected from two distinct environments. Days to flowering, evaluated at C.E.B 2017, ranged from 48 to 71 days and from 44 to 69 days, and at C.E.G 2016, they ranged from 53 to 81 days and from 53 to 75 days, in experiment 1 and 2, respectively. Discrepancies among locations in the experiments are probably due to the geographic position and the fact that irrigation was not provided at C.E.G. Furthermore, the crop cycle varied according to the water availability, which is a known strategy of sorghum plants to escape drought.

In Table 5, the estimated correlation coefficients between FLO or PL and SM were negative and significant, indicating that the bigger the panicle length and the later the flowering, the

Table 8. Genotype mean squares (MS), significances from ANOVA, in forage (E1) and grain (E2) sorghum experiments, for dry matter (DM), grain yield (GY) and seed mass (SM) evaluated at C.E.Bebedouro, 2017.

Sources		Dry Matter		Grain Yield		Seed Mass	
		E1	E2	E1	E2	E1	E2
	df	MS. 10^6	MS. 10^6	MS. 10^6	MS. 10^6	MS	MS
Genotypes	24	165.045**	169.815**	13.864**	18.626**	0.899**	0.941**
Error	48	33.178	56.407	2.443	2.932	0,052	0,113
Mean		28.5	20.7	5,340	5,987	26.8	30.6
CV%		20.18	36.33	29.26	28.60	8.53	10.97

**: Significant at 1% probability according to F-test.

Table 9. Genotype mean squares (MS), significances from ANOVA, in forage (E1) and grain (E2) sorghum cultivars, for days to flowering (FLO) and panicle length (PL).

Sources		C.E.B. 2017		C.E.G 2016			
		Days to Flowering		Days to Flowering		Panicle Length	
		E1	E2	E1	E2	E1	E2
	df	MS	MS	MS	MS	MS.10^4	MS.10^4
Genotypes	24	185.66**	143.037**	296.281**	168.28**	46.23**	29.15**
Error	48	2.289	4.463	4.573	3.104	5.60	3.77
Mean		57.02	54.71	62.17	58.84	0.22 m	0.24 m
CV%		2.65	4.07	3.44	2.99	11.00	7.93

**: Significant at 1% probability according to F-test.

DOI: https://doi.org/10.18512/rbms2020v19e1179

smaller the seeds are, while a highly significant coefficient of 46.54% was found between FLO and PL, indicating an important panicle development before blooming.

Genotypes can be tailored, according to the purpose of use, through conventional breeding. The best forage cultivars had the tallest plants and open panicle (SF-11 and SF-15), while grain cultivars were considerably shorter and had compact panicle. Double purpose genotypes tend to combine those traits as it can be seen in BRS Ponta Negra, with intermediate plant height and compact panicle.

Conclusions

Sorghum plants are fully adapted to the semi-arid environment and the grain and forage production of sorghum cultivars are not limited by temperature during plant development.

The water supply through drip irrigation provides grain and forage yield at outstanding levels in the semi-arid environment.

The genotypes with the best performance as to GM production are EP 17, SF 11, BRS 506 and SF 15, while SF-11, SF-15, 13F03(1141562), BR 506 and EP-17 are the most productive in regard to DM.

The genotypes 9910032, BRS Ponta Negra and ICVS 400 present distinguishable grain yield superior to 10 t ha^{-1}.

Acknowledgments

To the Brazilian Agricultural Research Corporation - Embrapa (SEG 23.13.06.014.00.00).

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