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Adaptability and stability of sweet sorghum cultivars

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Abstract - *The objective of this study was to evaluate the phenotypic stability and adaptability of 25 sweet sorghum cultivars of Embrapa Maize and Sorghum. The experiments were conducted in five Brazilian environments, three in the state of Minas Gerais, and the others in Sinop, Mato Grosso and Pelotas, Rio Grande do Sul. Fresh biomass yield (FBY), and total soluble solids (TSS) of the juice were evaluated in a randomized complete block design with three replications. Analysis of variance showed significant genotype by environment interaction for both traits. According to the Annicchiarico methodology analysis, genotypes CMSXS634, BRS506, and CMSXS646 were the most stable and adapted for FBY and TSS concomitantly; CMSXS634 being more adapted to favorable environments and CMSXS646 being more adapted to unfavorable environments.*

Key words: Sorghum bicolor*, genotype x environment interaction, Annicchiarico, biofuel, ethanol.*

INTRODUCTION

Among the main energy crops, sweet sorghum stands out as a very promising feed stock, resulting in many studies by different researches worldwide. Studies related to the bioenergy potential of sweet sorghum for ethanol production have been conducted in Europe (Venturi and Venturi 2003), Asia (Zhang et al. 2010), Oceania (Thomas 2009), Africa (Diaz-Chaves and Jamieson 2010), and the Americas (Kim and Day 2010, Guigou et al. 2011).

Sweet sorghum, similar to sugar cane, has succulent stems with the presence of directly fermentable sugars, which allows for harvesting and processing with the same infrastructure for ethanol production in sugar cane mills (Kim and Day 2010) and sugar cane ethanol plants. Sorghum is a short cycle crop, approximately four months, with established production systems for forage cultivars. The sorghum crop is established from seed and the production system is fully mechanized (Ratnavathi et al. 2010). For this reason, sweet sorghum may be an excellent potential to supply raw feed stock during the off season of sugar cane mills in Brazil from February to April, and thereby strengthen the national

production of ethanol, reduce the idle period of these mills, and reduce fluctuations of ethanol price.

Commercial release of new sweet sorghum cultivars requires understanding the performance of potential genotypes in different environmental conditions. Genotype by environment interactions can complicate the recommendation of cultivars for different environments, making adaptability and stability analyses necessary. The study of adaptability and stability allows the identification of genotypes with predictable behavior in specific or general environments, and the identification of genotypes sensitive to positive environmental variations (Cruz et al. 2004).

There are several methods for analyzing adaptability and stability of genotypes when grown in different environments. The choice of using certain analytical method of experimental data depends mainly on the number of environments available, the accuracy required, and the type of information desired. Ideally, the assessment methodology should be reliable, easy to interpret, require few statistics, and can be used for both small and large numbers of environments (Schmildt et al. 2011).

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The Annicchiarico (1992) method is based on analysis of variance, and stands out because it is of easy use. This method is based on the estimation of a risk index recommendation of using certain cultivar. For that, genotypic averages are converted to a percentage base in relation to the average values of a specific environment. Thus, the mean and standard deviation are estimated for each genotype and environment in relation to the normal distribution adopted to estimate the probability of a genotype to be above average of the sites studied.

In Brazil, some authors have conducted adaptability and stability studies of forage sorghum genotypes (Oliveira et al. 2002, Silva et al. 2005). However, there is a lack of information about the adaptability and stability of sweet sorghum genotypes. Thus, the objective of this study was to evaluate phenotypic stability and adaptability for fresh biomass yield and total soluble sugar of sorghum cultivars, developed by Embrapa Maize and Sorghum.

MATERIAL AND METHODS

The experiments were conducted in the 2009/2010 season at five different locations, three in Minas Gerais state; Sete Lagoas (lat 19º 27' 57'' S, long 44º 14' 49'' W, alt 767 m asl), Nova Porteirinha (lat 15º 47 ' 00'' S, long 43º 18' 00'' W, alt 533 m asl), and Jaíba (lat 15º 20' 16'' S, long 43º 40' 26'' W, alt 470 m asl); in Sinop – Mato Grosso (lat 11º 50' 53'' S, long 55º 38' 57'' W, alt 384 m asl), and in Pelotas – Rio Grande do Sul (lat 31º 46' 19'' S, long 52º 20' 34'' W, alt of 7 m asl), Brazil.

Sowing took place on October 29, in Sete Lagoas; November 17, in Jaíba; December 3, in Nova Porteirinha; December 17, in Pelotas; and February 9, in Sinop. The experiments were conducted during the rainy season in the South and Southeast regions, and the second harvest season in the Sinop, at the central-western Brazil.

Supplemental irrigation was applied at Sete Lagoas, Nova Porteirinha, and Jaíba trials during dry periods. Trials in Sinop and Pelotas were conducted under rainfed conditions. Other normally recommended cropping practices were applied during crop development in each region.

Twenty five cultivars of sweet sorghum belonging to the breeding program of Embrapa Maize and Sorghum were evaluated, 24 varieties (BR500, BR501, BR503, BR504, BR505, BRS506, BRS507, CMSXS629, CMSXS630, CMSXS631, CMSXS632, CMSXS633, CMSXS634, CMSXS635, CMSXS636, CMSXS637, CMSXS638, CMSXS639, CMSXS642, CMSXS643, CMSXS644, CMSXS646, CMSXS647 and CMSXS648), and one hybrid (BRS601).

The experimental plots consisted of four rows, 5 m long, spaced 0.70 m, established in a randomized complete block design with three replications. Fertilization consisted of 400 kg ha^{-1} of NPK (08-28-16) applied at sowing, and 200 kg ha^{-1} of urea applied 30 days after sowing. The plant population adopted was 125,000 plants ha^{-1}.

Evaluations were conducted in the two central rows of each plot. Determination of fresh biomass yield (FBY) was determined based on the weight of total plants in each plot, without panicles, harvested at grain physiological maturity, with the weight in kg per plot converted to t ha^{-1}. The content of total soluble solids (TSS) was determined using an automatic digital refractometer, measured in ° Brix.

Analysis of variance was first conducted for each environment. After verifying the assumptions of homogeneity of residual variances, analysis of variance for all sites and the Scott-Knott test (1974) at 5% probability were performed. Finally, adaptability and stability analysis was conducted, after determining significant genotype by environment interaction.

The genetic model adopted for the analysis of variance was $Y_{ijk} = \mu + G_i + A_j + GA_{ij} + B/A_{jk} + e_{ijk}$, where: Y_{ijk}: observation of ith genotype in j^{th} environment, and in k^{th} block; μ: general mean; G_i: i^{th} genotype effect ($i = 1, 2, …, 25$); A_j: j^{th} environment effect ($j = 1, 2, …, 5$); GA_{ij}: interaction effect of the ith genotype in j^{th} environment; B/A_{jk}: effect of kth block in j^{th} environment ($k = 1, 2$ and 3); e_{ijk}: random error. Genotype and environment effects were considered fixed.

The Annicchiarico (1992) methodology was adopted to study the adaptability and stability. This methodology allows estimating a confidence index (Wi) for a given genotype classified above the average performance between environments. It is considered the ideal genotype that provides the lowest risk of being adopted, in other words, the genotype that presents the greatest absolute value for the confidence index.

The model for the analysis of adaptability and stability is based on the formula $W_i = \overline{Y}_{i.} - Z_{(1-\alpha)} \cdot S_i$, where: W_i: confidence index (%); $\overline{Y}_{i.}$: average of ith genotype in percentage; $Z_{(1-\alpha)}$: cumulative normal distribution function; S_i: standard deviation of ith genotype in percentages.

High confidence index occur for genotypes that have higher averages and less deviation for traits evaluated. The value of the standardized normal distribution $Z_{(1-\alpha)}$ set was 0.2734, for $\alpha = 25\%$, which represents 75% level of confidence that the genotypes, at minimum, had values above the environmental average.

After analyzing the adaptability and overall stability, the confidence index was determined according to favorable or unfavorable environments, considering the means and the variances related to each type of environment. For this reason, environmental indices (Ij) were calculated as the difference between each environment mean and the overall mean from all environments. These indices classified the environmental conditions during the trials as favorable when positive and unfavorable when negative.

Thus, $W_{i(f)} = \overline{Y}_{i.(f)} - Z_{(1-\alpha)} \cdot S_{i(f)}$ only considers environments classified as favorable, and $W_{i(d)} = \overline{Y}_{i.(d)} - Z_{(1-\alpha)} \cdot S_{i(d)}$ only considers environments classified as unfavorable. All statistical analyses were performed using the Genes software (Cruz 2009).

RESULTS AND DISCUSSION

According to F test in the joint analyzes (Table 1), genotype by environment interaction showed significant effects (P < 0.01) for FBY and TSS. This indicates distinct performance changes of sweet sorghum cultivars evaluated in different environments. The Scott-Knott (1974) cluster means test was used for classification of FBY (Table 2) and TSS means (Table3).

Table 1. Summary of joint analysis of variance for fresh biomass yield (FBY), and content of total soluble solids (TSS) of 25 genotypes of sweet sorghum, grown in different environments, in 2009/2010 season in Brazil

Source of variation	df	MS	
		FBY (t ha^{-1})	TSS (°Brix)
Genotypes (G)	24	198.16**	39.50**
Environments (E)	4	7651.70**	152.37**
G x E	96	93.62**	6.00**
Blocks/E	10	155.59	12.95
Error	240	41.46	3.21
C.V.(%)		14.86	10.38

** and *: Significant at 1% and 5% probability for the F test, respectively.

Overall environment means for FBY ranged from 27.31 t ha^{-1} in Pelotas - RS to 51.62 t ha^{-1} in Nova Porteirinha - MG. Teixeira et al. (1999) presented similar results when evaluating the sorghum cultivar BR505, in different seasons, with values ranging from 20.85 t ha^{-1} to 52.70 t ha^{-1}.

The value observed for Pelotas – RS can be considered underestimated due to the occurrence of a prolonged drought without supplemental irrigation during plant growth. In this environment, there were no significant differences between genotypes, and the coefficient of variation of 26.90% was

Table 2. Average of fresh biomass yield (FBY)*, in t ha^{-1}, of 25 cultivars of sweet sorghum grown in five environments, in 2009/2010 season in Brazil

Genotypes	Environments															Means
	Sete Lagoas-MG			Nova Porteirinha-MG			Jaíba-MG			Pelotas-RS			Sinop-MT			
CMSXS629	48.48	b	A	53.90	a	A	35.76	b	B	27.57	a	B	51.33	a	A	43.41
CMSXS630	57.24	a	A	46.52	b	A	46.71	a	A	26.48	a	B	48.10	b	A	45.01
CMSXS631	46.00	b	A	50.14	b	A	39.38	b	A	32.33	a	B	45.52	b	A	42.67
CMSXS632	46.19	b	A	43.38	b	A	36.81	b	B	26.14	a	B	45.05	b	A	39.51
CMSXS633	49.05	b	A	53.81	a	A	42.29	a	B	22.00	a	C	40.19	b	B	41.47
CMSXS634	53.81	a	A	55.95	a	A	32.57	b	B	37.29	a	B	57.62	a	A	47.45
CMSXS635	49.81	b	A	49.52	b	A	35.29	b	B	32.76	a	B	49.24	a	A	43.32
CMSXS636	40.48	b	A	45.29	b	A	30.90	b	B	15.90	a	C	44.48	b	A	35.41
CMSXS637	53.43	a	A	48.05	b	A	28.90	b	B	25.67	a	B	43.33	b	A	39.88
CMSXS638	50.29	b	A	54.19	a	A	37.90	b	B	28.05	a	B	37.14	b	B	41.51
CMSXS639	47.24	b	A	46.90	b	A	39.76	b	A	23.19	a	B	47.33	b	A	40.88
BRS506	49.05	b	A	59.62	a	A	43.05	a	B	30.05	a	C	55.62	a	A	47.48
CMSXS642	48.57	b	A	43.48	b	A	31.62	b	B	28.62	a	B	54.48	a	A	41.35
CMSXS643	65.14	a	A	49.62	b	B	41.57	a	B	21.14	a	C	43.90	b	B	44.27
CMSXS644	63.90	a	A	63.14	a	A	43.22	a	B	35.24	a	B	45.62	b	B	50.22
BR507	48.19	b	A	52.29	b	A	44.48	a	A	25.14	a	B	44.48	b	A	42.92
CMSXS646	60.19	a	A	48.67	b	B	44.29	a	B	26.62	a	C	42.86	b	B	44.53
CMSXS647	58.19	a	A	60.43	a	A	48.43	a	B	28.43	a	C	61.33	a	A	51.36
CMSXS648	47.43	b	B	61.29	a	A	40.71	a	C	31.43	a	C	52.86	a	B	46.74
BR500	44.19	b	A	45.86	b	A	30.95	b	B	26.81	a	B	52.19	a	A	40.00
BR501	48.00	b	B	57.14	a	A	54.29	a	A	18.33	a	C	41.81	b	B	43.91
BR503	52.95	a	A	49.76	b	A	47.52	a	A	23.91	a	B	27.05	b	B	40.24
BR505	56.29	a	A	46.90	b	A	37.48	b	B	30.86	a	B	49.90	a	A	44.29
BR504	40.48	b	A	44.38	b	A	37.33	b	A	26.62	a	B	46.86	b	A	39.13
BRS601	49.71	b	A	60.19	a	A	45.33	a	B	32.29	a	C	43.33	b	B	46.17
Means	50.97			51.62			39.86			27.31			46.86			43.32

* means followed by the same lowercase and same capital letters do not differ at same column and row, respectively, by Scott Knott test at 5% probability.

Table 3. Averages of total soluble solids (TSS)* in ºBrix of 25 cultivars of sweet sorghum grown in five environments, in 2009/2010 season in Brazil

Genotypes	Environments															Means
	Sete Lagoas-MG			Nova Porteirinha-MG			Jaíba-MG			Pelotas-RS			Sinop-MT			
CMSXS629	18.5	a	A	16.6	a	A	18.7	a	A	15.9	a	A	16.9	c	A	17.3
CMSXS630	18.4	a	A	14.6	b	B	18.9	a	A	16.9	a	A	18.2	b	A	17.4
CMSXS631	19.0	a	A	16.4	a	A	18.5	a	A	18.6	a	A	21.0	a	A	18.7
CMSXS632	18.7	a	A	15.1	b	B	18.5	a	A	15.1	b	B	18.2	b	A	17.1
CMSXS633	20.1	a	A	18.4	a	A	19.4	a	A	18.6	a	A	22.1	a	A	19.7
CMSXS634	19.7	a	A	16.8	a	B	21.5	a	A	17.8	a	B	21.4	a	A	19.4
CMSXS635	13.2	c	B	15.1	b	B	20.2	a	A	13.2	b	B	13.4	d	B	15.0
CMSXS636	19.2	a	A	14.8	b	B	19.3	a	A	11.7	b	C	16.6	c	A	16.3
CMSXS637	21.4	a	A	17.5	a	B	18.8	a	B	18.2	a	B	20.9	a	A	19.4
CMSXS638	18.6	a	A	12.4	c	B	18.4	a	A	16.5	a	A	17.1	c	A	16.6
CMSXS639	19.4	a	A	17.2	a	B	19.6	a	A	16.8	a	B	16.1	c	B	17.8
BRS506	20.3	a	A	15.5	b	B	18.5	a	A	16.1	a	B	20.1	a	A	18.1
CMSXS642	20.4	a	A	17.4	a	B	19.6	a	A	18.0	a	B	21.7	a	A	19.4
CMSXS643	18.7	a	A	14.6	b	A	16.8	a	A	16.7	a	A	17.6	c	A	16.9
CMSXS644	16.8	b	A	15.3	b	A	16.7	a	A	13.7	b	A	16.5	c	A	15.8
BR507	19.7	a	A	17.8	a	B	19.9	a	A	17.6	a	B	21.2	a	A	19.2
CMSXS646	19.9	a	A	18.8	a	A	20.0	a	A	17.9	a	A	18.4	b	A	19.0
CMSXS647	16.3	b	A	14.1	b	B	17.9	a	A	14.3	b	B	16.4	c	A	15.8
CMSXS648	20.1	a	A	13.0	c	C	16.6	a	B	15.3	b	C	17.2	c	B	16.4
BR500	19.0	a	A	11.7	c	B	18.3	a	A	16.8	a	A	18.4	b	A	16.8
BR501	16.7	b	A	15.6	b	A	18.0	a	A	16.7	a	A	15.3	c	A	16.5
BR503	16.6	b	A	11.7	c	B	17.5	a	A	13.9	b	B	11.7	d	B	14.3
BR505	17.3	b	A	17.0	a	A	19.5	a	A	17.3	a	A	17.8	b	A	17.8
BR504	18.7	a	A	14.4	b	B	17.0	a	A	13.3	b	B	18.5	b	A	16.4
BRS601	13.7	c	A	14.3	b	A	15.8	b	A	13.9	b	A	12.2	d	A	14.0
Means	18.4			15.4			18.6			16.0			17.8			17.2

* means followed by the same lower case and same capital letters do not differ at the same column and row, respectively, by Scott Knott test at 5% probability.

higher compared with all other environments, that showed values ranging from 9.36% to 16.59%.

Similarly, the genotypes showed significant differences in all environments for TSS, with the overall mean ranging between 15.4 º Brix in Nova Porteirinha - MG and 18.6 º Brix in Jaíba - MG. The average values for FBY and TSS of this study confirmed data presented by Channappagoudar et al. (2007). Since these characters are positively correlated with ethanol production (Guigou et al. 2011), cultivars with the highest values for both characters are the most suitable for agronomic processing.

Thirteen genotypes (CMSXS629, CMSXS630, CMSXS634, CMSXS635, BRS506, CMSXS643, CMSXS644, CMSXS646, CMSXS647, CMSXS648, BR501, BR505 and BRS601) had FBY higher than the overall mean (43.32 t ha^{-1}) across environments, and CMSXS629, CMSXS630, CMSXS634, BRS506, CMSXS646, and BR505

were also present in the group that showed superior performance for TSS compared to overall environment mean of 17.2 º Brix. Although the other genotypes showed significant FBY, they had low measurement for TSS, or vice-versa.

According to the environments classification, Sete Lagoas – MG, and Sinop - MT were considered favorable environments for both FBY and TSS. Nova Porteirinha - MG was classified as favorable for FBY and unfavorable for TSS, and Jaíba - MG was classified as unfavorable for FBY and favorable for TSS. Lastly, Pelotas - RS was classified as unfavorable for both traits (Table 4).

From the adaptability and overall stability assessment, we observed that the genotypes CMSXS647, CMSXS644, CMSXS634, BRS506, CMSXS648, CMSXS630, CMSXS646, CMSXS635 and BRS601 had the lowest risk of having behavior below average for FBY, considering 75% confidence (Table 5). For TSS, genotypes CMSXS633,

Table 4. Environmental indices (Ij) and classification of favorable or unfavorable environments for cultivation, according to the methodology of Annicchiarico (1992). Values obtained by evaluating the characters of fresh biomass yield (FBY) and content of total soluble solids (TSS) of 25 genotypes of sorghum, grown in five environments, in the season 2009/2010 in Brazil

Environment	FBY		TSS	
	Index	Class	Index	Class
Sete Lagoas - MG	5.69	Favorable	1.16	Favorable
Nova Porteirinha - MG	6.34	Favorable	-1.80	Unfavorable
Jaíba - MG	-5.42	Unfavorable	1.31	Favorable
Pelotas - RS	-17.97	Unfavorable	-1.22	Unfavorable
Sinop - MT	1.58	Favorable	0.55	Favorable

Table 5. Parameters of adaptability and overall stability (Wi) in favorable environments ($Wi_{(f)}$) and in unfavorable environments ($Wi_{(d)}$) of 25 genotypes of sweet sorghum for fresh biomass yield (FBY), in t ha^{-1}, based on the methodology of Annicchiarico (1992), according to results obtained in five different environments in 2009/2010 season in Brazil

General		Favorable environments		Unfavorable environments	
Genotype	Wi	Genotype	Wi$_{(f)}$	Genotype	Wi$_{(d)}$
CMSXS647	114.85	CMSXS647	118.26	BRS601	115.10
CMSXS644	112.87	CMSXS634	110.81	CMSXS644	114.74
CMSXS634	107.32	CMSXS644	109.76	CMSXS647	109.42
BRS506	105.47	CMSXS643	106.81	BRS506	108.61
CMSXS648	105.41	CMSXS630	104.51	CMSXS648	106.10
CMSXS630	104.47	CMSXS648	101.02	CMSXS631	104.80
CMSXS646	100.82	BRS506	100.67	CMSXS630	103.14
BRS601	100.24	CMSXS635	99.77	CMSXS646	101.64
CMSXS635	99.32	CMSXS629	98.72	BR505	99.83
CMSXS643	98.18	CMSXS646	98.65	CMSXS634	98.52
CMSXS629	97.82	BR507	98.25	CMSXS635	98.16
BR507	97.44	CMSXS639	97.27	BR507	98.04
CMSXS631	96.72	CMSXS637	95.88	CMSXS638	97.42
BR505	94.83	CMSXS642	94.95	BR503	97.24
CMSXS638	93.35	CMSXS633	94.89	BR504	94.82
CMSXS639	92.44	CMSXS631	94.14	CMSXS632	93.38
CMSXS633	92.02	BRS601	93.75	CMSXS629	93.16
CMSXS642	91.86	CMSXS638	93.37	CMSXS639	89.46
CMSXS632	91.51	BR505	92.88	CMSXS633	88.38
BR501	90.43	BR501	91.90	BR501	88.30
CMSXS637	89.04	BR 500	90.63	CMSXS642	87.13
BR 500	88.98	CMSXS632	88.61	CMSXS643	85.65
BR504	88.17	BR504	85.59	BR 500	83.94
BR503	86.70	CMSXS636	85.23	CMSXS637	79.09
CMSXS636	75.79	BR503	79.23	CMSXS636	64.15

CMSXS642, CMSXS634, CMSXS637, BR507, CMSXS646, CMSXS631, BRS506, BR505 and CMSXS639 had the lowest risk (Table 6). However, only genotypes CMSXS634, BRS506, and CMSXS646 showed high risk indices ($W_i >$ 100) considering FBY and TSS simultaneously, qualifying them as the most stable and suitable for ethanol production in all environments (Figure 1).

Some genotypes, such as CMSXS647 in favorable environments, and BRS601 in unfavorable environments, presented high W_i for FBY, with performances 18.26% and 15.10% higher than average. But for TSS, they were 8.58% and 11.54% lower than average, respectively. The reverse also occurred to CMSXS642 in favorable environments, and CMSXS633 in unfavorable environments, which

Table 6. Parameters of adaptability and overall stability (Wi) in favorable environments ($Wi_{(f)}$) and in unfavorable environments ($Wi_{(d)}$) of 25 genotypes of sorghum, for total soluble solids (TSS) or ºBrix in the juice, based in the methodology of Annicchiarico (1992), according to results obtained in five different environments in the 2009/2010 season in Brazil

General		Favorable environments		Unfavorable environments	
Genotype	Wi	Genotype	$Wi_{(f)}$	Genotype	$Wi_{(d)}$
CMSXS633	112.44	CMSXS634	112.48	CMSXS633	117.07
CMSXS642	111.06	CMSXS642	110.51	CMSXS646	114.71
CMSXS634	111.04	CMSXS633	109.71	CMSXS637	113.61
CMSXS637	110.75	CMSXS637	109.29	CMSXS642	112.42
BR507	110.26	BR507	109.25	BR507	111.57
CMSXS646	108.76	CMSXS646	105.88	CMSXS634	109.42
CMSXS631	106.43	BRS506	105.70	CMSXS631	109.29
BRS506	102.95	CMSXS631	104.26	BR505	108.54
BR505	101.66	CMSXS630	101.09	CMSXS639	106.76
CMSXS639	101.43	BR 500	100.98	BR501	101.78
CMSXS630	99.81	CMSXS632	100.66	CMSXS629	101.68
CMSXS629	99.24	CMSXS636	98.76	BRS506	100.25
CMSXS632	98.20	BR505	98.23	CMSXS630	98.04
CMSXS643	96.44	CMSXS638	98.17	CMSXS643	97.44
BR 500	93.83	CMSXS639	98.16	CMSXS632	95.38
BR501	93.69	CMSXS629	97.71	CMSXS647	89.79
CMSXS638	93.52	BR504	97.15	CMSXS644	89.65
CMSXS648	92.40	CMSXS648	95.77	BRS601	88.46
BR504	92.39	CMSXS643	95.45	CMSXS648	87.49
CMSXS647	90.74	CMSXS647	91.42	CMSXS638	87.33
CMSXS636	90.48	CMSXS644	90.86	CMSXS635	87.01
CMSXS644	90.31	BR501	89.74	BR504	86.28
CMSXS635	82.80	CMSXS635	79.53	BR 500	84.76
BR503	79.26	BR503	79.04	CMSXS636	79.80
BRS601	78.79	BRS601	73.74	BR503	79.04

presented performance 10.51% and 17.07% higher than average for TSS and presented performance 5.05% and 11.62% below the average for FBY, respectively.

The genotypes that have excelled in favorable environmental conditions (Sete Lagoas - MG and Sinop - MT) for both characters were CMSXS634, CMSXS630, and BRS506, since they showed confidence indices above the environmental average for both FBY and TSS. In percentage, these genotypes exceeded the environmental average by 10.81%, 4.51% and 0.67% for FBY and by 12.48%, 1.09% and 5.70% for TSS, respectively. Likewise, genotypes CMSXS631, BRS506, and CMSXS646 stood out in unfavorable environment (Pelotas - RS), for presenting concurrently, confidence indices above average for both FBY (4.8%, 8.61% and 1.64%) and for TSS (9.29%, 0.25% and 14.71%).

The Annicchiarico method allowed easy interpretation, based on analysis of only one parameter, and also allowed the ranking of genotypes more adapted and stable. Silva et al. (2005), using another method of stability and adaptability to evaluate fresh and dry biomass yield in forage sorghum cultivars, identified BRS506, among the materials evaluated, as the most suitable to favorable and unfavorable environments, in addition to presenting the highest yield for fresh biomass (49.33 t ha^{-1}). In the present study, the cultivar BRS506 also showed general and specific adaptability and stability for favorable and unfavorable environments for both FBY and TSS. However, the genotype CMSXS634 showed superior performance in general adaptation and in particular favorable environments, moreover, genotype CMSXS646 presented general and specific adaptation to unfavorable environments for both traits.
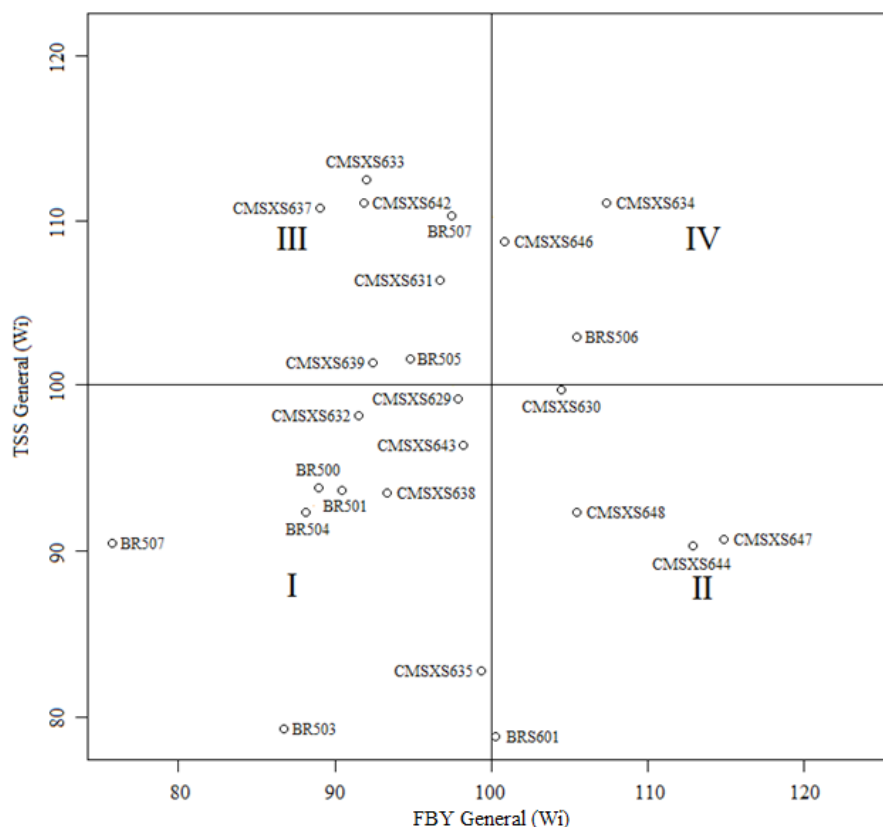
Figure 1. Display of the overall standings of the 25 sweet sorghum cultivars grown in five different environments in 2009/2010 season in Brazil, evaluated for fresh biomass yield (FBY) and total soluble solids (TSS), according to the method of Annicchiarico (1992). Quadrant I: Genotypes without adaptability and overall stability for FBY and TSS. Quadrant II: Genotypes with adaptability and overall stability for FBY. Quadrant III: Genotypes with adaptability and overall stability for TSS. Quadrant IV: Genotypes with adaptability and overall stability for FBY and TSS.

These results indicate that improvements have been made in the sweet sorghum breeding program of Embrapa Maize and Sorghum, since higher yielding cultivars, adapted and stable for both general and specific environments were observed, being possible candidates for commercial release. Moreover, they can assist in the decision of farmers in adopting new cultivars. However, new studies of the adaptability and stability in different seasons and in new environments are important to obtain more complete information on the performance of genotypes in specific regions.

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Adaptabilidade e estabilidade de cultivares de sorgo sacarino

Resumo - *O objetivo do presente estudo foi avaliar a adaptabilidade e estabilidade fenotípica de 25 cultivares de sorgo sacarino da Embrapa Milho e Sorgo. Os experimentos foram conduzidos em cinco ambientes, três no Estado de Minas Gerais e os demais nas cidades de Sinop – MT e Pelotas – RS, no delineamento em blocos ao acaso, com três repetições. Foram avaliados a produção de biomassa fresca (PBF) e o teor de sólidos solúveis totais (SST) do caldo. Na análise de variância conjunta, a interação genótipos com ambientes foi significativa para os dois caracteres avaliados. Para análise da adaptabilidade e estabilidade, utilizou-se o método de Annicchiarico. Os genótipos CMSXS634, BRS506 e CMSXS646 foram os mais adaptados e estáveis para PBF e SST concomitantemente, sendo CMSXS634 mais adaptado a ambientes favoráveis e CMSXS646 a ambientes desfavoráveis.*

Palavras-chave: Sorghum bicolor*, interação genótipos x ambientes, Annicchiarico, biocombustível, etanol.*

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