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Stability analysis in sweet sorghum [*Sorghum bicolor* (L.) Moench] using Eberhart and Russell`s model

P Kavya, V Satyanarayana Rao, JV Ramana, B Sreekanth, Y Radhakrishna and SK Nafeez Umar

Abstract
The study was conducted using 16 F_1 hybrids, their corresponding 8 parents and one hybrid check (CSH 22SS) which were evaluated at three different locations of Andhra Pradesh covering three different environments *viz*., Agricultural College Farm, Bapatla; Regional Agricultural research Station, Lam, Guntur; Agricultural Research station, Garikapadu during rabi season of 2018. The experiment was conducted in a Randomized Block Design with three replications at all the three locations. The experimental data were analysed using Eberhart and Russell model based on these stability parameters, regression coefficient (S2di), mean performance ($\bar{x}$) and linear response (bi). Bapatla location was found to be most favourable location for brix %, total soluble sugars, ethanol yield and seed yield. Guntur was the most favourable location for juice yield while Garikapadu was the favourable for fresh stalk yield. The hybrid H-11 is found to be suitable for unfavourable environments in respect of, grain yield and juice yield. The hybrids H-3 and H-4 were found to be more stable in respect of both Brix per cent and TSS per cent.

Keywords: Sweet sorghum, stability, Eberhart and Russell model

Introduction
Sweet sorghum is similar to grain sorghum [*Sorghum bicolor* (L.) Moench] but have been selected to accumulate high levels of sucrose in the parenchyma of juicy stems (Harlan and deWet, 1972) [1] The present commercial ethanol production in India is only through sugarcane, where the by-product from sugar refineries *i.e.*, molasses which is utilised for the ethanol production. When compared to sugarcane, the juice from sweet sorghum is possessing high amounts of reducing sugars which aids in the efficient fermentation, producing clear and potable ethanol with low aldehydes (Ratnavathi *et al.* 2003) [2]. The juice extraction and fermentation procedures are similar to sugarcane without much differences. The cultivable land under sugarcane is decreasing year by year. The added advantages of sweet sorghum are four months of crop period when compared to sugarcane 12-13 months of crop period, where three crops cane be harvested in a single year with 300% cropping intensity, while the water consumption is nearly three times lower (8,000 m^3 ha^{-1}) than sugarcane (36,000 m^3 ha^{-1}). (Vinutha *et al*. 2014) [3].
The countries *viz;* Brazil, The United States of America (USA) and China are the top ethanol producing countries respectively, while India stands in 4th position producing around 2000 million litres of ethanol, primarily from sugarcane molasses. (Prasad *et al*. 2018) [4]. In order to reduce carbon monoxide emission through automobiles, Indian government has mandated for blending of five per cent ethanol with petrol and diesel and could save nearly 80 million liter of petrol annually, if petrol is blended with ethanol by 10 per cent. (GAIN report 2013) [6]. The government has no stringent regulations for blending ethanol in petrol (gasoline) due to truncated production of sugarcane crop and it's byproduct in the past decade. The sweet sorghum can be a best alternative for ethanol production to meet up the demand of the country, by providing year the round operations to molasses-based ethanol distilleries and provide an assured income to the farmers.
Generally, most of the sweet sorghum productivity traits are governed by non-additive gene actions as they are influenced by environment (Pagire *et al.,* 2020) [5]. Hence an effort was made to study the stability of hybrids for various traits as there is scarce information available.

Materials and Methods

The 16 F_1 hybrids, their corresponding 8 parents and one hybrid check (CSH 22SS) were evaluated at three different locations of Andhra Pradesh covering three different environments *viz*., Agricultural College Farm, Bapatla; Regional Agricultural research Station, Lam, Guntur; Agricultural Research station, Garikapadu during rabi season of 2018. The experiment was conducted in a Randomized Block Design with three replications at all the three locations. Each entry was sown and raised in two rows of 4 m length with 60×15 cm spacing. Recommended agronomic practices were followed throughout the crop season. In each replication, observations were recorded on 10 randomly selected competitive plants. The experimental data were analyzed using Eberhart and Russell model based on these stability parameters, regression coefficient (S2di), mean performance ($\bar{x}$) and linear response (bi). At physiological maturity, data was recorded on following traits.

Fresh Stalk Weight (T ha^{-1})

The fresh weight of each cane (from base of the stem to upper most node) at physiological maturity after removal of leaf and leaf sheath was recorded and converted to tonnes per hectare.

Juice yield (l ha^{-1})

Total quantity of juice obtained by crushing the cane (harvested at physiological maturity stage) using roller crusher was collected in a measuring jar and the volume was recorded and converted to litre per hectare.

Brix per cent (Per cent)

This was measured by taking the extracted juice of the cane on to the space provided for the same in Hand refractometer having a capacity to measure 0 to 34 per cent brix.

Total Soluble Sugars (Per cent)

It is the total fermentable sugars such as glucose, fructose, and sucrose *etc.* including starch in the juice. For predicting the total soluble sugars by using juice Brix, the following regression equation given by Corleto and Cazzato (1997), as reported by Reddy *et al.* (2005) was used.

Total Soluble Sugars (TSS) = 0.1516 + (Brix % × 0.8746)

Computed ethanol yield (l ha^{-1})

Computed ethanol yield (CEY) is measure using the following formula

Total sugar yield (t/ha) = [(TSS %) /100] X Juice yield (L/ha)/1000

CEY = Total sugar yield (t/ha)/5.68) x 3.78 x 1000 x 0.8 **(**Smith, G.A and Buxton. 1993)

TSS = Total Soluble Sugars

Grain yield (T ha^{-1})

The total cleaned grains obtained after threshing of each panicle was weighed and recorded, converted hectare plant yield to tonnes/hectare.

Results and Discussions

Mean performance, range and environmental index values in different environments

The data recorded on 13 quantitative characters of sweet sorghum in three locations analysed E_1- Bapatla, E_2- Guntur, E_3- Garikapadu and the mean, range and environmental indices are presented trait-wise in Table:1.

Fresh stalk yield (T ha^{-1})

Among the environments, higher mean value for fresh stalk weight was recorded in E_3 environment (48.00 T ha^{-1}), followed by E_1 (44.787 T ha^{-1}) environmental indices ranged from -5.17 to 4.44. Among the hybrids, the highest value was recorded by H-3 (68.76 T ha^{-1}) and H-5 recorded minimum value (30.23 T ha^{-1}) in Bapatla location and in Guntur location highest value was recorded by H-11 (68.82 T ha^{-1}) and lowest in H-8 (15.70 T ha^{-1}). Garikapadu location H-13 (73.20 T ha^{-1}) recorded the highest value while lowest in H-14 (30.47 T ha^{-1})

Juice yield (l ha^{-1})

High variation was observed for juice yield between environments as evident from range of environmental indices (-871.29 to 507.40) and environmental means (12489.31 l ha^{-1} to 13798.03 l ha^{-1}). However, maximum range was observed in E_2 environment (5444.44 l ha^{-1} to 25029.30 l ha^{-1}). Among the hybrids in Bapatla, Guntur and Garikapadu locations following hybrids has recorded highest values H-3 (22742.57 l ha^{-1}), H-15 (25029.60 l ha^{-1}) H-7 (21955.53 l ha^{-1}) and lowest in H-16 (6844.44 l ha^{-1}), H-4 (5444.44 l ha^{-1}), H-15 (5792.59 l ha^{-1}) in respective locations.

Brix %

Environmental indices and environment mean for this trait ranged from -1.31 to 1.18 in E_3 & 12.12 to 14.38 per cent in E_1, respectively. Maximum amount of variability for this character was expressed in environment-1 (14.38 per cent) while E_3 showed the least (10.72 per cent). Across the environments, Bapatla location H-8 (18.50 per cent) has recorded the highest and lowest in H-14 (9.50 per cent), in Guntur location H-11 (18.50 per cent) recorded highest brix percent and H-10 (9.50 per cent) has registered lowest brix per cent. In Garikapadu location, highest brix percent was recorded by H-9 (16.50 per cent) and lowest brix percent by H-6 (8.00 per cent).

Total soluble sugars (%)

Environmental indices and environmental mean for this character varied from -1.148 to 1.038 and 10.72 to 12.71 per cent respectively. The maximum range within the environment was in E_2 (6.71 to 16.33). Across the environments, Bapatla location H-7 (16. 33 per cent) has recorded the highest and lowest in H-14 (8.46 per cent), in Guntur location H-7 (16.33 per cent) recorded highest brix percent and H-10 (6.71 per cent) has registered lowest brix per cent. In Garikapadu location, highest brix percent was recorded by H-9 (15.45 per cent) and lowest brix percent by H-6 (7.15 per cent).

Ethanol yield (l ha-1)

Variation in ethanol yield is noticed across the environments as indicated by varying environmental indices (-114.41 to 95.19) and environmental means too varied from 734.43 to 921.12 l ha^{-1}. The range for this character varied from 372.66 to 1651.84 l ha^{-1} in E_2 followed by 530.83 to 1874.27 l ha^{-1} in E_1 and 314.72 to 1249.52 l ha^{-1} in E_3 environment, when compared to check performance in 3 locations CSH-22SS (553.42 l ha^{-1}, 555.57 l ha^{-1}, 683.59 l ha^{-1}) the following hybrids has recorded the highest values H-3 (1874.27 l ha^{-1}), H-7 (1597.93 l ha^{-1}) in Bapatla location, H-15 (1651.84 l ha^{-1}), H-2 (1342.03 l ha^{-1}) in Guntur location, H-9 (1249.52 l ha^{-1}) and H-8 (1249.52 l ha^{-1}) in Garikapadu location respectively.

Grain yield (T ha^{-1})

The maximum environmental index and environmental mean were recorded at E_1 (0.23 and 4.70 respectively) while these were low at E_2 (-0.29 and 4.18). The overall mean performance of hybrids among three locations are as follows, H-3 (6.74 T ha^{-1}) recorded high grain yield in Bapatla location, H-15 (6.51T ha^{-1}) recorded the highest grain yield in Guntur location and in Garikapadu location H-9 (6.95 T ha^{-1}) recorded the highest when compared to check entry CSH-22SS (3.39 T ha^{-1}, 3.14 T ha^{-1} and 3.82 T ha^{-1}) at three respective locations.

Environmental Index (%)

Environmental index revealed the suitability of an environment. Based on the positive values of environmental index, for 16 hybrids (Table 1.) Bapatla location was found to be the most favourable location for brix % (1.18), total soluble sugars (1.038), ethanol yield (95.19) and grain yield (0.238) whereas the environment -2 at Guntur was the most favourable location for juice yield (507.40). However environment-3 *i.e.*, Garikapadu was found to be favourable for fresh stalk yield (4.44). Diasa *et al.* (2017) [9] reported similar results for Brix per cent.

Stability Parameters

The three stability parameters *viz.*, mean, regression co-efficient (bi) and deviation from linear regression line (S^2di) were estimated for all the traits and the results obtained are presented in Tables: 2 to 4.

The genotypes with higher mean values than general mean value, regression coefficient value of unity (bi = 1) and non-significant deviation from linear regression (S^2di = 0) were considered as stable and adapted to varied environmental conditions. However, genotypes with a higher mean value than general mean value and value of regression coefficient more than unity (bi > 1) with non-significant deviation from linear regression were considered to be below average stable, and hence suitable for favourable environmental condition. Further, genotypes with higher mean values than general mean values and regression coefficient less than unity (bi < 1) and non-significant deviations from linear regression were considered as above average stable, and hence are suitable for poor environmental condition.

Fresh stalk yield (T ha^{-1})

The stability parameters in respect of fresh stalk yield are given in table 2. Out of the 16 hybrids tested over three locations, the hybrid H-3 has recorded maximum fresh stalk yield (62.15 T ha^{-1}) and H-5 has recorded minimum fresh stalk yield (35.65 T ha^{-1}) and the average over three environments was 44.17 T ha^{-1}. Regression value was significant and more than unity for hybrid, H-14. Deviation from regression was significant for 14 hybrids and rest two hybrids *viz.*, H-9 and H-14 registered non-significant for deviation from regression.

None of the hybrids have recorded higher mean value than grand mean with regression coefficient around unity (bi=1) and non-significant deviation from regression.

Juice yield (l ha^{-1})

The stability parameters for juice yield are given in table 2. Out of 16 hybrids tested, H-7 has recorded juice yield (18348.13 l ha^{-1}) while, H-12 has recorded the lowest juice yield (8720.98 l ha^{-1}) and mean over three environments was 13532.9 l ha^{-1}.

The hybrid H-8 has differed significantly from unity for regression coefficient. The deviation from regression value was non-significant for H-8, H-11 and H-12.

Regression coefficient less than one (bi<1) with higher mean value than general mean and non-significant deviation from regression were observed in H-1(bi=0.49) and H-11(bi=0.68). These hybrids would perform better in unfavourable environments.

Brix %

The stability parameters in respect of Brix per cent are given in table 3. Out of the 16 hybrids tested over three locations H-11 has recorded Brix (16%) and H-6 recorded minimum Brix per cent (10.33%) and the average over three locations was 13.28. Regression value was significant for hybrids, H-1, H-6 and H-13. Deviation from regression was significant for nine hybrids.

Hybrids H-3(bi=1.84) and H-4 (bi=1.63) have exhibited means greater than grand mean with regression coefficient around unity (bi=1) and non-significant deviation from regression. These hybrids were stable over variable locations. Regression coefficient less than one (bi<1) with high mean than general mean and non-significant deviation from regression were observed in H-2 (bi=-0.63). This hybrid would perform better in unfavourable environments. Whereas hybrid-15 (bi=2.36) having bi value greater than one with higher mean value than grand mean and non-significant deviation from regression was considered to perform well in favourable conditions.

Total soluble sugars (%)

The stability parameters for total soluble sugars are given in table 3. Out of 16 hybrids, H-11 has recorded the highest total soluble sugars (14.14%) while, H-6 has recorded the lowest total soluble sugars (9.19%) and mean over three locations was 11.77%. The three hybrids, H-1, H-6 and H-13 have differed significantly from unity for regression coefficient. The deviation from regression value was significant for nine hybrids *viz.*, H-5, H-7, H-8, H-9, H-10, H-11, H-12, H-14 and H-16. The genotypes which have recorded the highest total soluble sugars are more desirable for this character.

Hybrids H-3(bi=1.84) and H-4(bi=1.63) had higher mean than grand mean with regression coefficient around unity (bi=1) and non-significant deviation from regression. Hence, these hybrids were considered to possess the average stability for total soluble sugars at different locations. Regression coefficient less than one (bi<1) with higher mean than general mean and non-significant deviation from regression were observed in H-2(bi=-0.62). This hybrid would perform better in unfavourable environments. Regression coefficient more than one (bi>1) with higher mean value than general mean and non-significant deviation from regression was observed in H-15 (bi=2.36) which is expected to perform well in favourable environments.

Ethanol yield (l ha^{-1})

The stability parameters in respect of ethanol yield are given in table 4. Out of the 16 hybrids tested over three locations, H-3 recorded maximum ethanol yield (1345.9 l ha^{-1}) and H-12 recorded minimum ethanol yield (493.3 l ha^{-1}) and the average over three environments was 852.0 l ha^{-1}. Regression value was non-significant for all the hybrids. None of the hybrids have recorded higher mean than grand mean with regression coefficient around unity (bi=1) and non-significant deviation from regression.

Grain yield (T ha^{-1})

The stability parameters in respect of grain yield are given in table 4. Out of the 16 hybrids tested over three locations H-5 has recorded maximum grain yield (5.34 T ha^{-1}) and H-16 has (3.40 T ha^{-1}) recorded minimum grain yield and the average over three locations was 4.54 T ha^{-1}. None of the hybrids were significant for regression coefficient. Deviation from regression was significant for nine hybrids *viz.*H-1, H-2, H-4, H-6, H-7, H-9, H-10, H-14 and H-15.

Regression coefficient less than one (bi<1) with high mean than general mean and non-significant deviation from regression were observed in H-5 (bi=-3.71), H-11 (bi=-0.16) and H-12 (bi=0.42). These genotypes would perform better in unfavourable environments. Whereas, hybrid H-8 (bi=3.00) having bi value greater than one with higher mean value than grand mean and non-significant deviation from regression was considered to perform well in favourable conditions.

Table 1: Summary of mean, range and environment index values in respect of six traits across three environments in 16 sweet sorghum [*Sorghum bicolor* (L.) Moench] hybrids

S. No.	Character	Mean			Range			Environmental index		
		Env 1	Env 2	Env 3	Env 1	Env 2	Env 3	Env 1	Env 2	Env 3
1	FSTK	44.78	39.55	48.00	30.23- 68.76	15.70 – 68.82	30.47 – 73.20	0.73	-5.17	4.44
2	JY	13574.44	13798.03	12489.31	6844.44 – 22742.57	5444.44 – 25029.60	5792.59 – 21955.53	363.8	507.40	-871.29
3	BRIX %	14.38	13.24	12.12	9.50 – 18.50	7.50 – 18.50	8.00 – 18.50	1.18	0.12	-1.31
4	TSS	12.71	11.83	10.72	8.46– 16.33	6.71 – 16.33	7.15 – 15.45	1.038	0.109	-1.148
5	EY	921.12	852.67	734.43	530.83 – 1874.27	372.66 – 1651.84	314.72 – 1249.52	95.19	19.21	-114.41
6	GY	4.70	4.18	4.55	2.31– 6.74	1.96 – 6.51	2.21 – 6.95	0.238	-0.296	0.058

FSTK= Fresh stalk yield (T ha^{-1}), JY= Juice yield (l ha^{-1}), Brix %, TSS = Total soluble sugars (%), EY= Ethanol yield (l ha^{-1}), GY = Grain yield (T ha^{-1}).

Env 1-Bapatla, A.P Env 2- Guntur, A.P Env 3- Garikapadu, A.P

Table 2: Stability parameters in respect of Fresh stalk yield (T ha^{-1}), Juice yield (l ha^{-1}) traits in 16 F_1 hybrids of sweet sorghum [*Sorghum bicolor* (L.) Moench]

S. No.	Cross	1. Fresh stalk yield (T ha^{-1})			2. Juice yield (l ha^{-1})		
		µ	bi	σ^2di	µ	bi	σ^2di
H-1	ICSA 14029 x SEVS-08	43.31	-0.93	129.56**	14281.46	0.49	563089.98**
H-2	ICSA 14029 x GGUB 28	46.11	0.48	318.35**	17180.23	2.61	14180199.59**
H-3	ICSA 14029 x ICSV-15006	62.15	-0.87	79.19**	18066.65	0.85	35017950.00**
H-4	ICSA 14029 x IS 29308	45.01	2.78	308.15**	7817.27	-1.79	4536533.90**
H-5	ICSA 14030 x SEVS -08	35.65	1.97	60.63**	10227.15	-4.76	5214430.22**
H-6	ICSA 14030 x GGUB 28	46.46	1.81	349.71**	15933.32	5.48	19894493.41**
H-7	ICSA 14030 x ICSV 15006	61.53	1.96	17.41**	18348.13	-4.33	4506607.06**
H-8	ICSA 14030 x IS 29308	27.80	1.99	32.95**	11316.04	-8.76*	-250801.85
H-9	ICSA 14033 x SEVS-08	35.96	0.17	0.62	13397.52	-0.94	36639452.58**
H-10	ICSA 14033 x GGUB -28	41.18	2.28	142.40**	17876.53	2.55	6433357.84**
H-11	ICSA 14033 x ICSV-15006	59.14	-2.18	44.45**	14234.55	0.68	-103774.08
H-12	ICSA 14033 x IS-29308	43.39	2.43	303.42**	8720.98	-0.75	-109926.48
H-13	ICSA 14035 x SEVS-08	46.26	3.71	440.16**	12812.33	5.28	18702849.45**
H-14	ICSA 14035 x GGUB 28	36.22	-1.28*	-0.31	10251.84	3.10	22118445.22**
H-15	ICSA 14035 x ICSV-15006	38.18	0.21	132.97**	16286.41	12.37	13423530.648**
H-16	ICSA 14035 x IS-29308	38.36	1.47	122.11**	9775.29	3.90	34062724.514**
CHK	CSH-22SS	43.92	-1.08	43.92	9725.9	-1.26	1602309.3
	Population mean over 3 locations	44.17 T ha^{-1}			13522.9 l ha^{-1}		

bi: Regression coefficient

* and **: Significant at 5 and 1 per cent level respectively

S2di: Mean square deviation from regression coefficient

Table 3: Stability parameters in respect of Brix % and Total soluble sugars traits in 16 F_1 hybrids of sweet sorghum [*Sorghum bicolor* (L.) Moench]

S. No.	Cross	3. Brix %			4. Total soluble sugars (%)		
		µ	bi	σ^2di	µ	bi	σ^2di
H-1	ICSA 14029 x SEVS-08	11.33	-1.61*	-.18	10.06	-1.61*	-0.14
H-2	ICSA 14029 x GGUB 28	14.00	-0.63	0.07	12.39	-0.62	0.05
H-3	ICSA 14029 x ICSV-15006	15.66	1.84	0.35	13.85	1.84	0.27
H-4	ICSA 14029 x IS 29308	13.83	1.63	0.12	12.25	1.63	0.09
H-5	ICSA 14030 x SEVS -08	11.66	1.50	3.89**	10.35	1.50	2.98**
H-6	ICSA 14030 x GGUB 28	10.33	1.80*	-0.20	9.19	1.80*	-0.15

H-7	ICSA 14030 x ICSV 15006	14.66	2.51	3.11**	12.98	2.51	2.38**
H-8	ICSA 14030 x IS 29308	15.66	0.70	4.40**	13.85	0.70	3.35**
H-9	ICSA 14033 x SEVS-08	12.83	-1.11	40.57**	11.37	-1.11	31.06**
H-10	ICSA 14033 x GGUB -28	12.00	-1.14	8.19**	10.64	-1.14	6.27**
H-11	ICSA 14033 x ICSV-15006	16.00	2.73	6.84**	14.14	2.73	5.23**
H-12	ICSA 14033 x IS-29308	12.00	2.55	0.81*	10.64	2.55	0.62*
H-13	ICSA 14035 x SEVS-08	11.33	1.40*	-0.20	10.06	1.40**	-0.16
H-14	ICSA 14035 x GGUB 28	11.33	-0.24	10.78**	10.06	-0.24	8.27**
H-15	ICSA 14035 x ICSV-15006	14.33	2.36	0.39	12.68	2.36	0.30
H-16	ICSA 14035 x IS-29308	15.50	1.71	4.62**	13.70	3.90	3.52**
CHK	CSH-22SS	13.00	-0.23	0.50	11.52	-0.24	0.38
	Population mean over 3 locations	13.28%			11.77%		

bi: Regression coefficient
* and **: Significant at 5 and 1 per cent level respectively
S2di: Mean square deviation from regression coefficient

Table 4: Stability parameters in respect of Ethanol yield and Grain yield traits in 16 F_1 hybrids of sweet sorghum [*Sorghum bicolor* (L.) Moench].

S. No.	Cross	5. Ethanol yield (l ha^{-1})			6. Grain yield (T ha^{-1})		
		μ	Bi	σ^2di	μ	Bi	σ^2di
H-1	ICSA 14029 x SEVS-08	764.9	-1.20	1444.40	4.03	0.98	1.43**
H-2	ICSA 14029 x GGUB 28	1130.3	-0.18	69402.73**	4.73	-0.54	0.48*
H-3	ICSA 14029 x ICSV-15006	1345.9	3.63	124268.34**	5.06	5.99	0.08
H-4	ICSA 14029 x IS 29308	506.1	0.49	29515.59**	4.56	6.45	1.28**
H-5	ICSA 14030 x SEVS -08	535.3	-0.19	25747.38**	5.34	-3.71	-0.08
H-6	ICSA 14030 x GGUB 28	815.4	3.87	16440.40**	4.45	0.32	1.45**
H-7	ICSA 14030 x ICSV 15006	1259.7	1.23	182897.10**	4.55	4.63	1.94**
H-8	ICSA 14030 x IS 29308	802.4	-3.32	50814.87**	4.80	3.00	-0.10
H-9	ICSA 14033 x SEVS-08	777.1	-.80	18871.40**	4.77	-3.68	8.74**
H-10	ICSA 14033 x GGUB -28	1004.0	0.25	73165.23**	4.82	0.23	0.5*
H-11	ICSA 14033 x ICSV-15006	1078.6	2.39	43124.86**	4.77	-0.16	-0.11
H-12	ICSA 14033 x IS-29308	493.3	1.06	6707.91*	5.16	0.42	-0.15
H-13	ICSA 14035 x SEVS-08	696	1.87	107023.03**	3.89	1.25	0.30
H-14	ICSA 14035 x GGUB 28	533.1	1.51	-1751.93	4.24	1.50	0.45*
H-15	ICSA 14035 x ICSV-15006	1150.3	6.08	225655.84**	4.04	-5.15	3.54**
H-16	ICSA 14035 x IS-29308	740.1	1.30	417676.90**	3.40	4.46	0.08
CHK	CSH-22SS	597.5	-0.72	11113.1	5.01	-17.22	12.03
	Population mean over 3 locations	852.00 l ha^{-1}			4.54 T ha^{-1}		

bi: Regression coefficient
* and **: Significant at 5 and 1 per cent level respectively
S2di: Mean square deviation from regression coefficient

Conclusion

The hybrid H-11 is found to be suitable for unfavourable environments in respect of, grain yield and juice yield. The hybrids H-3 and H-4 were found to be more stable in respect of both Brix per cent and TSS per cent. The above quoted results are in accordance with Rao *et al.* (2011) [10], Udoh *et al.* (2018) [11] for brix Per cent, Rohmani *et al*. (2006) [12], Umakanth *et al.* (2012) [13], Vange *et al.* (2014) [14], Anarse *et al.* (2016) [15], Khandelwal *et al*. (2019) [16] for grain yield whereas the results for biomass by the above authors are deviating from the current results. It is clear that in respect of fresh stalk yield and ethanol yield none of the hybrids are suitable to any environment.

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