Genetic variation and correlation of some agronomic traits, biomass and ethanol yield in diverse sweet sorghum (Sorghum bicolor L. Moench) cultivars

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ABSTRACT: Genetic diversity is important for the improvement in the genetic makeup of any crop, and the genetic inclusion of diverse parents in hybrid programs. Sweet sorghum (Sorghum bicolor L. Moench) contains high sugar-rich stalks like sugarcane. Sweet sorghum germplasm accessions were used in the improvement program to develop high total soluble solids, biomass yield and other characteristics related to total soluble solids, biomass yield and ethanol yield. The objectives of this study were to evaluate sweet sorghum cultivars introduced from different countries for flowering days, stalk diameter, plant height, stripped stalk weight, biomass yield, total soluble solids, harvest index, ethanol percentage, ethanol yield, and SPAD chlorophyll meter reading (SCMR); and determine the correlations among these traits to understand whether SCMR can be used as an indirect selection criterion for biomass yield and other traits. The experiment was conducted in the late rainy season in 2011. Fifteen sweet sorghum cultivars were arranged in a randomized complete block design with three replications under rain-fed conditions with supplemental irrigation. Significant differences among cultivars were observed for plant height (PH), stripped stalk weight (SSW), biomass yield (BY), total soluble solids (TSS), SCMR at days to 50% flowering, harvest index (HI), ethanol percentage, and ethanol yield (EY). PH positively and significantly correlated with SSW, BY, HI and EY. Stalk diameter (SD) positively and significantly correlated with BY, SSW, PH and SCMR. SSW positively and significantly correlated with BY, HI and EY. TSS positively and significantly correlated with ethanol percentage, HI and EY. SCMR positively correlated with BY. Keller, Theis, BJ248, KKU40, and SPV1411 were selected for further evaluation as well as immediate and further use in the sweet sorghum breeding program because these varieties showed good characteristics required for sweet sorghum improvement.

Keywords: SPAD value, phenotypic selection, correlation, brix, sweet sorghum cultivar

INTRODUCTION

Sweet sorghum (*Sorghum bicolor* L. Moench) has high sugar content in stalks (Rao Dayakar et al., 2004; Ratnavathi et al., 2011), and sugar content is usually higher than 8 brix (Pfeiffer et al., 2010). Sweet sorghum is therefore a fermentable sugar source for bio-ethanol production (Ratnavathi et al., 2010; Alhajturki et al., 2012). Pure lines of sweet sorghum have been used as an alternative crop for bio-ethanol production for a decade in the United Sates (Pfeiffer et al., 2010; Pedersen et al., 2012), China (Hana et al., 2011) India (Umakanth et al., 2012) and Africa (Woods, 2001).

In previous investigations, both hybrids (Makada et. al., 2009) and pure lines (Ratnavathi et al., 2010) were evaluated for yield performance and

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ethanol production. Sweet sorghum shows heterosis for many characters such as sugar yield (Pfeiffer et al., 2010; Pedersen et al., 2012), stalk yield (Pfeiffer et al., 2010), total biomass, juice yield, ethanol yield (Umakanth et al., 2012), plant height (Meshram et al., 2005; Pfeiffer et al., 2010) and total soluble solid (Makanda et al., 2009; Umakanth et al., 2012). Most research on sweet sorghum in many countries has focused on the development of F_1 hybrids to exploit the expression of heterosis for these characters. Sweet sorghum hybrids are now being developed in many countries such as in China (Umakanth et al., 2012) United State (Pfeiffer et al., 2010; Peterson et al., 2012) and India (Reddy et al., 2005).

In Thailand, some hybrid development of sweet sorghum were also reported, two F_1 hybrids (L103×KKU 40 and L103×Urja) were promising for stalk yield, juice yield and ethanol yield (Pothisoong and Jaisil, 2011). The parents of the hybrids were later converted to A_3 cytoplasm for further development of sweet sorghum hybrids using cytoplasmic genetic male sterility system. Currently, more elite sorghum varieties from many sources have been introduced for use as working germplasm in our sweet sorghum breeding program. This newly-introduced germplasm must be evaluated for total soluble solid, biomass yield, stripped stalk yield and ethanol yield for further development in our sweet sorghum hybrid breeding program.

In previous investigations in sweet sorghum, plant height and stalk diameter were positively correlated with biomass yield (Audilakshmi et al., 2010; Han et al., 2012), total soluble solid (Audilakshmi et al., 2010; Guigou et al., 2011), stripped stalk yield, sugar yield (Han et al., 2012), sugar content (Guigou et al., 2011) and sucrose content (Ritter et al., 2008). Moreover, SPAD chlorophyll meter reading (SCMR) by Minolta SPAD-502 meter was used for indirect assess of chlorophyll content in many crops such as grain sorghum (Xu et al., 2000), maize, soybean (Markwell et al., 1995), cotton (Wu et al., 1998), rice (Jinwen et al., 2009), wheat (Udding et al., 2007) and peanut (Arunyanark et al., 2009). SCMR has used for indirect measurement of chlorophyll content in plant leaves because SCMR and chlorophyll content had highly positive correlation such as in grain sorghum (Xu et al., 2000), wheat (Udding et al. 2007) and rice (Jinwen et al., 2009). High chlorophyll content indicates high photosynthetic capacity and biomass production. Therefore, SCMR is indirectly related to yield because part of biomass is converted to harvestable yield.

The questions underlying this research project are which sweet sorghum cultivars have high potential for further use in sweet sorghum breeding programs based on ethanol yield and agronomic traits and whether SCMR can be used as a selection tool for crop productivity in sweet sorghum. The objectives of this study were to evaluate sweet sorghum cultivars from different countries for ethanol yield and agronomic traits and determine the correlations among characters under investigation to understand whether SCMR is related to crop productivity in sweet sorghum. This information is useful for selecting sweet sorghum cultivars as parents in sweet sorghum breeding program and using SCMR as an alternative trait to evaluate crop productivity in sweet sorghum.

MATERIALS AND METHODS

Plant material

Fifteen sweet sorghum cultivars were evaluated in this study. Eight cultivars [Urja, SP4484-2, ICSV93046, RSSV9, SSV84, SPV1411, ICSV25274 and CSH22SS (hybrid variety)] were kindly donated from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Four cultivars (Keller, Bailey, Theis and Cowley) were introduced from USA (Ali et al., 2008). Two cultivars (BJ248 and BJ281) were introduced from China (Audilakshmi et al., 2010) and one cultivar (KKU40) was released from Khon Kaen University, Thailand. These sweet sorghum cultivars are pure lines and were selected for evaluation because they have high yield and use as commercial varieties in their origin countries.

Field Experiment

The field trial was carried out at the Field Crops Research Station, Khon Kaen University in 2011. Fifteen cultivars were assigned in randomized complete block design with three replications. The plants were grown in four-row plots with 4 m in length and spacing of 50 cm between rows and 20 cm between plants. The seeds were over-planted manually and the seedlings were later thinned to obtain 1 plant per hill at 15 days after planting. The fertilizer grade 15-15-15 (N-P-K) at rate 156.25 kg ha^{-1} was applied into experiment plots at two splits during sowing and top dressing after planting 30 days or 4 weeks after manual weeding. Sweet sorghum was planted under rainfed condition and water was applied once a week by sprinkler system. Carbosulfan was used for protect shootfly damage with basal fertilizer when planting sweet sorghum and 30 days after planting.

Phenotypic measurements

The soil plant analysis development (SPAD) chlorophyll meter reading (SCMR) was measured 3 times at days to 50% flowering, 10 and 20 days after days to 50% flowering. The SCMR was measured in 10 plants in each plot at 3rd leaf from the top on three positions of leaf blade using Minolta SPAD-502 meter.

Number of days to 50% flowering was recorded when 50% of plants in the plot had 50% flowering. The plants in 2 m^2 in each plot were harvested manually at hard dough stage or 30 days after days to 50% flowering by cutting the stems at the base of the plants with a scissor.

Plant height was recorded from 5 plants in each plot from the ground level to the panicle tip of the stems. Stalk diameter was measured using digital vernier caliper at the middle nodes of 5 plants in each plot. Biomass yield was recorded from 2 m^2 in each plot and was converted to 1 ha. Stripped stalk weight was measured from 2 m^2 in each plot by removing panicle and leaves and the data were converted to 1 ha. Total soluble solid was measured by using hand-held refractometer at hard dough stage. Total soluble solid was recorded from three parts of five stems (base, middle and tip) and the data were averaged into single value for each plot. Percent ethanol and ethanol yield were calculated following Somani and Taylor (2003). Harvest index was calculated from economic yield divided by biomass yield (stripped stalk weight divided by biomass yield).

Statistical analysis

Analysis of variance (ANOVA) was performed in each trait. Duncan's multiple range test (DMRT) was used to compare mean differences. Simple correlations among characters under study were computed for agronomic traits. The analysis was done using MSTAT-C package (Bricker, 1989).

RESULTS AND DISCUSSION

Elite sweet sorghum cultivars were collected from different parts of the world such as from the United States, China, India and Thailand. These varieties have been used for commercial production in their original countries, and they were evaluated under growing conditions in Thailand with supplemental irrigation to avoid severe drought. The purpose of this evaluation was to see which varieties had good adaptation for further use as germplasm source for hybrid development.

Variations in yield and agronomic traits

Significant differences among 15 sweet sorghum cultivars were observed for plant height, stripped stalk weight, biomass yield, total soluble solid, SCMR at flowering, harvest index, percent ethanol and ethanol yield, but the differences were not significant for days to flowering and stalk diameter (**Table 1**).

Plant height ranged between 210.80 to 290.00 cm and the variety BJ284 had the highest plants. In previous investigations in sweet sorghum, plant height ranged between 104 to 348 cm and Keller, Bailey Cowley and Theis were common to our study (Ali et al., 2008). In other investigations, plant height ranging between 178 to 257 cm (Pedensen et al., 2012), 64 to 198 (under well-water condition) and 57 to 185 (under low moisture stress condition) (Alhajturki et al., 2012), 205 to 283 cm (Pfeiffer et al., 2010) and 115.4 to 219.9 cm (Makanda et al., 2009) were reported.

The range of plant height in report of Pfeiffer et al. (2010) was comparable to our study, while the range of plant height in Ali et al. (2008) was higher and wider although some varieties are common to our study. The ranges of plant height in other studies were lower than in our study. The crop in the study of Ali et al. (2008) was higher because it was grown in temperate region where temperature was lower and day length was longer. Sorghum with plant height lower than in our study might be subjected to some types of stresses.

Stripped stalk yield ranged between 24.47 to 64.64 tons ha^{-1}, whereas biomass yield ranged between 39.66 to 89.04 tons ha^{-1} (**Table 1**). It is interesting to note here that Keller had the highest stripped stalk yield and biomass yield, and ICSV25274 had the lowest stripped stalk yield and biomass yield.

In previous investigations, stripped stalk weights ranging between 33.08 to 45.92 tons ha^{-1} (Channappagoudar et al., 2007), 22.76 to 44.85 tons ha^{-1} (Chavan et al., 2009), 7.89 to 49.46 tons ha^{-1} (Makada et al., 2009), 11.46 to 76.26 tons ha^{-1} (under well-water) (Alhajturki et al., 2012) and 21 to 30 tons ha^{-1} (Umakanth et al., 2012) were reported, while biomass yields ranged between 34.46 to 74.88 tons ha^{-1} (Chavan et al., 2009), 25.38 to 42.34 tons ha^{-1} (Ratnavathi et al., 2011) and 31 to 54 tons ha^{-1} (Umakanth et al., 2012). Data of stripped stalk yield and biomass yield provided similar information of yield performance of sweet sorghum.

For stripped stalk, sorghum in the study of Alhajturki et al. (2012) had higher yield than did in our study, and the range of yield was also wider. Other studies reported lower stripped stalk yield than in our study. For biomass yield, only yield in the study of Chavan et al. (2009) was slightly lower than in our study, but yields in other studies were considerably lower. The results indicated that sweet sorghum productivity in Thailand is comparable to that produced in different regions of the world.

Total soluble solids in this study ranged between 9.33 in Urja to 16.33 brix in Theis (**Table 1**). In previous studies, the total soluble solids ranging between 7.13 to 19.26 brix (Ali et al., 2008), 11.66 to 18.66 brix (Alhajturki et al., 2012), 18.4 to 20.7 brix (Pfeiffer et al., 2010), 14.7 to 18.68 brix (Rattnavathi et al., 2011), 10.1 to 13.2 brix (Davila-Gomez et al., 2011) and 6.5 to 12 brix (Makanda et al., 2009).

From five studies, there were three studies that reported higher ranges of total soluble solid than in our study and two studies that reported lower ranges of total soluble solid than in our study. The results indicated that range of total soluble solid in this study was intermediate among other studies, and there is a gap for improvement of total soluble solid.

SCMR ranged between 36.03 to 48.36 in SSV84 and Urja, respectively (**Table 1**). Urja also had the highest SCMR at 10 days after flowering and SSV84 also had the lowest SCMR at 10 days after flowering (data not reported). Sweet sorghum cultivars were not significantly different for SCMR at 20 days after flowering (data not reported).

Direct comparison for SCMR in sweet sorghum is not possible because, to the best of our knowledge, this information has not been reported elsewhere. However, in 98 recombinant inbred lines of grain sorghum, SCMR values ranging from about 15 to 52 were reported (Xu et al., 2000). The range in previous study was higher and wider than in this study possibly due to contrasting parents for SCMR in previous study. In this study, the appropriate time for evaluation of SCMR was within 10 days of flowering stage. SCMR is thus more appropriate for germplasm evaluation than selection among uniform line.

Harvest index values based on fresh weight ranged between 0.60 in CSH22SS to 0.82 in ICSV93046 (**Table 1**). In previous findings, non-stripped harvest index of sweet sorghum was 0.90 (Biosystems and Agricultural Engineering Department, 2006) and the harvest index values ranged between 0.48 and 0.73 for stripped canes (Shinde et al., 2013). The non-stripped harvest index was higher than in our study because it included leaves and sheaths. Harvest index in our study was about 10% higher than those in previous study and the differences between these reports would be possibly due to the different practices in removal of sheaths and leaves.

Ethanol percentages ranged between 4.39 in Bailey to 8.35 in Theis, and ethanol yield ranged between 720.00 in Cowley to 2,708.30 l ha^{-1} in Keller (**Table 1**). It is interesting to note here that the varieties with the high percent ethanol did not have the highest ethanol yield and KKU40 and Keller had similar ethanol yield.

In previous studies, ethanol yields ranged between 1,570 to 4,500 l ha^{-1} (Ratnavathi et al., 2010), 720.26 to 1,051.53 l ha^{-1} (Davila-Gomez et al., 2011), 916 to 2,283 l ha^{-1} (Pedersen et al., 2012) and 484.27 to 3,050.67 l ha^{-1} (Alhajturki et al., 2012). The range of ethanol yield in our study was two

times higher than that reported in Davila-Gomez et al. (2011) and slightly higher than that reported in Pedersen et al. (2012). However, the range of ethanol yield in our study was much lower than that reported in Alhajturki et al. (2012) and Ratnavathi et al. (2010). In general, ethanol yield is dependent largely on sugar content in each variety, agronomic practices and growing conditions, and comparison of the results from different studies indicated that the possibility to improve ethanol yield in sweet sorghum is also high.

Days to 50% flowering among 15 sweet sorghum cultivars ranged between 59 to 76 days, and sweet sorghum cultivars were not significantly different for this trait (**Table 1**). In previous studies, it ranged between 58 to 100 days under well-water condition and 67 to 132 days under low moisture stress (Alhajturki et al., 2012), 65 to 96 days (Pedersen et al., 2012) and 57 to 113 days (Ali et al., 2008).

All previous studies reported the range of days to flowering longer than in our study although some cultivars in their study were common to this study. The differences in days to flowering in different investigations were due mainly to cultivars and environments. Sweet sorghum is a short day plant, and number of days to flowering of sweet sorghum is determined partially by growing degree day and photoperiod (Reddy et al., 2011). Number of days to flowering is an important character in sweet sorghum as it determines harvest maturity, and it is useful for production planning and logistics of raw materials.

Stalk diameter ranged between 10.50 to 12.63 mm, and sweet sorghum cultivars were not significantly different for this trait. In previous studies, stalk diameter ranged between 8.2 to 14.8 mm (Makanda et al., 2009), 18.2 to 21.6 mm (Pfeiffer et al., 2010) and 10 to 40 mm (Alhajturki et al., 2012). All previous studies reported bigger stalks than in this study. The differences in stalk diameter in different studies might be due to measuring methods, cultivars and environments.

Phenotypic correlation among traits

Correlations among characters under study were presented in **Table 2**. Days to flowering was positively and significantly correlated with plant height (r=0.39**) and ethanol yield (r=0.47**). Plant height was also correlated with ethanol yield (r=0.54**), showing that these trait were inter-related. However, days to flowering was not correlated with stalk diameter, stripped stalk weight, biomass yield, total soluble solid, SCMR, harvest index and percent ethanol.

The correlations among plant height, days to flowering and ethanol yield were intermediate in this study. In previous study, the correlations between plant height and days to flowering were r=0.41** (Codesido et al., 2013), r=0.56** and 0.66** (Zou et al., 2011). The results in previous study were similar to or higher than our findings.

In previous findings, stalk diameter was positively correlated with days to 50% flowering (Zou et al., 2011). The results were rather different from our study, and the reason for the contrasting results would be due to the uniformity of days to flowering in sorghum varieties.

Plant height, stripped stalk weight, biomass yield and stalk diameter were inter-related with correlation coefficients from r=0.56** between plant height and stalk diameter to r=0.93** between stripped stalk weight and biomass yield.

In previous findings, plant height was positively correlated with stalk yield and stem diameter (Audilakshmi et al., 2010; Alhajturki et al., 2012; Han et al., 2012). The inter-correlations have been well established in many crops that stalk is the harvestable yield.

Total soluble solid was not associated with days to flowering, stalk diameter, plant height, stripped stalk weight, biomass yield and SCMR, but it was closely related to harvest index (r=0.32**), percent ethanol (r=0.86**) and ethanol yield (r=0.48**).

In previous findings, total soluble solid was positively correlated with plant height (r=0.38**) and days to flowering (r=0.31**) (Zou et al., 2011). The results were rather contrasting with our results and the reason would possibly due to the uniformity for these traits in our germplasm because these varieties were selected because they performed well in their origin countries.

SCMR was not related to most characters under study except for stalk diameter (r=0.35**) and biomass yield (r=0.39**). In previous study Xu et al. (2000) found the highly positive correlation between SPAD value and chlorophyll content, for our study we found the positive correlation biomass yield, that mean chlorophyll content also has correlation with biomass. The low correlations between SCMR and productive traits indicated that this trait was not useful as selection criterion in these varieties.

Harvest index, percent ethanol and ethanol yield were inter-related with correlations from r=0.35** between harvest index and percent ethanol to r=0.57** between harvest index and ethanol yield. Harvest index was also closely related with plant height r=0.54**, stripped stalk weight r=0.62** and total soluble solid r=0.32*. Similarly, Ethanol yield was also closely related with plant height r=0.54**, stripped stalk weight r=0.54**, biomass yield r=0.38**, total soluble solid r=0.48**, and percent ethanol r=0.53**.

In previous investigations, harvest index was positively correlated with plant height and stripped stalk weight (Han et al., 2012), and stalk diameter had positive correlation with stalk yield and juice yield (Alhajturki et al., 2012). Fresh stalk yield (r=0.83**), juice yield (0.57**) and total soluble solid (0.55**) were the main contributors for ethanol yield (Rani and Umakanth, 2012). Stalk yield was also positively correlated with juice yield (Alhajturki et al., 2012), sugar yield and ethanol yield (Alhajturki et al., 2012; Han et al., 2012).

It is interesting to note here that growth characters such as plant height, stalk diameter, stripped stalk weight, and biomass were well associated, and these characters were also associated with harvest index. Association among growth characters is common in most crops, but association between growth characters and harvest index is dependent largely on which parts of the plants are used for harvestable yield.

In cereals such as rice, wheat, maize and grain sorghum in which grains are used as harvestable yield, the relationships between growth characters and harvest index is rather low. In contrast to the above, economic yield for sweet sorghum in this study is stalk, and therefore, the good association between harvest index and growth characters is not surprising.

Table 1 The performances of fifteen sweet sorghum cultivars for 10 characters in late rainy season in 2011.

Cultivars	Days to 50% flowering	Stalk diameter (mm)	Plant height (cm)	Stripped stalk weigh (t/ha)	Biomass yield (t/ha)	Total soluble Solid (°brix)	SCMR at days to 50% flowering	Harvest index	Percent ethanol	Ethanol yield (l/ ha)
BJ281	59	10.62	218.7^{c}	31.50^{ef}	47.31^{efg}	14.33^{abc}	42.21^{a-d}	0.667^{bcd}	6.94^{a-d}	929.20^{gh}
Keller	72	11.98	284.5^{ab}	64.64^{a}	89.04^{a}	15.33^{a}	47.93^{a}	0.733^{a-d}	7.80^{ab}	2708.30^{a}
Urja	65	10.88	228.9^{bc}	29.92^{ef}	44.21^{fg}	9.33^{d}	48.36^{a}	0.677^{bcd}	5.53^{a-d}	1427.50^{c-g}
SP4484-2	71	10.81	263.0^{abc}	36.83^{de}	52.68^{def}	12.00^{a-d}	37.71^{cd}	0.740^{a-d}	5.45^{bcd}	1453.80^{c-f}
Bailey	67	10.50	211.2^{c}	35.43^{de}	52.43^{def}	10.33^{bcd}	46.19^{ab}	0.677^{bcd}	4.39^{d}	1031.00^{e-h}
Theis	71	11.11	258.3^{abc}	41.99^{cd}	54.89^{def}	16.33^{a}	43.10^{abc}	0.687^{a-d}	8.35^{a}	1706.40^{cd}
ICSV93046	74	11.52	281.3^{ab}	58.97^{ab}	70.75^{b}	14.33^{abc}	46.36^{ab}	0.820^{a}	8.02^{ab}	1912.20^{bc}
BJ248	76	12.02	290.0^{a}	40.92^{cd}	57.97^{cde}	12.33^{a-d}	42.68^{a-d}	0.693^{a-d}	5.68^{a-d}	1369.70^{d-g}
RSSV9	65	11.50	252.3^{abc}	54.08^{b}	66.85^{bc}	14.00^{abc}	43.75^{abc}	0.767^{ab}	7.37^{abc}	1524.70^{cde}
SSV84	75	10.70	210.8^{c}	26.94^{f}	43.86^{fg}	14.33^{abc}	36.03^{d}	0.617^{cd}	7.11^{a-d}	1159.40^{e-h}
KKU40	72	11.65	260.3^{abc}	45.73^{c}	62.89^{bcd}	14.67^{ab}	44.29^{abc}	0.730^{a-d}	7.10^{a-d}	2279.90^{ab}
SPV1411	69	10.52	280.3^{ab}	40.50^{cd}	54.80^{def}	16.00^{a}	39.79^{bcd}	0.753^{abc}	7.90^{ab}	1319.20^{d-g}
Cowley	63	12.63	236.2^{abc}	35.82^{de}	58.04^{cde}	13.33^{a-d}	45.08^{ab}	0.617^{cd}	7.53^{abc}	720.00^{h}
CSH22SS	67	11.34	241.9^{abc}	30.57^{ef}	50.27^{efg}	10.00^{cd}	41.27^{a-d}	0.603^{d}	4.79^{cd}	774.00^{h}
ICSV25274	69	10.95	231.7^{bc}	24.47^{f}	39.66^{g}	13.33^{a-d}	41.36^{a-d}	0.687^{a-d}	6.50^{a-d}	1004.20^{fgh}
Mean	69	11.25	250.0	39.89	56.38	13.33	43.07	0.698	6.66	1421.30
	ns	ns	*	**	**	*	**	*	*	**
CV	10.49	10.48	11.54	11.22	11.30	17.48	8.43	10.27	21.69	18.50

*, ** and ns significant at P<0.05, 0.01 and non significant probability levels, respectively. Means in the same column followed by the same letter (s) are not significantly different (at P < 0.05) by DMRT

Table 2 Correlation coefficients of agronomic characteristics of fifteen sweet sorghum cultivars.

Traits	Days to 50% flowering	Stalk diameter	Plant height	Stripped stalk weight	Biomass yield	Total soluble solid	SCMR at days to 50% flowering	Harvest index	Percent ethanol
Stalk diameter	0.21								
Plant height	0.39**	0.56**							
Stripped stalk weight	0.24	0.60**	0.79**						
Biomass yield	0.22	0.72**	0.70**	0.93**					
Total soluble solid	0.19	0.03	0.18	0.28	0.19				
SCMR	0.08	0.35*	0.14	0.28	0.39**	-0.11			
Harvest index	0.14	0.04	0.54**	0.62**	0.30*	0.32*	-0.09		
Percent ethanol	0.10	0.06	0.17	0.25	0.13	0.86**	-0.02	0.35**	
Ethanol yield	0.47**	0.18	0.54**	0.54**	0.38*	0.48**	0.16	0.57**	0.53**

* significant at P<0.05, ** significant at P<0.01

Conclusion

Fifteen sweet sorghum cultivars introduced from different countries were evaluated for ethanol yield and other agronomic traits in this study, and the promising cultivars were selected based on these traits for further use in sweet sorghum breeding program. Keller, KKU40, BJ248, SPV1411 and Theis were selected for further evaluation for immediate ethanol production and further development in sorghum breeding program because these varieties showed good important characteristics i.e. total soluble solid, plant height, stalk diameter and strippted stalk weight. Total soluble solid, plant height and harvest index are promising selection criteria for ethanol yield in sweet sorghum. SCMR had low correlations with traits associated with ethanol yield and it is not useful as a selection criterion for ethanol yield in elite germplasm that are more uniform for SCMR but it may be useful for selection of SCMR in populations with high variation for this trait.

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