

Productivity of Sweet Sorghum Genotypes under Contrasting Fertility Management for Food and Ethanol Production

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Abstract

Sweet sorghum (*Sorghum bicolor* (L.) Moench) has a good potential for ethanol production in Ethiopia. However, continual supply of feed stock to the distillery is one of the major constraints in sweet sorghum-based ethanol and grain yield productions. A study was carried out in Ethiopia during the 2015 to 2016 crop seasons to determine the performance of sweet sorghum genotypes for their stability or specific adaptability under contrasting fertilizer rates across environments. All agronomic characters were varied with the genotypes and environments. Grain yield, panicle weight and plant height were also significantly varied with fertilizations, but other agronomic characters were not varied with fertilizations. The ethanol yield and quality components varied with genotypes, environments and fertilizations, but brix % was not varied with fertilizations. The genotypes, E36-1, ICSR 93034 and IESV 92207 DL, produced greater estimated sugar, ethanol, juice and fresh stalk yield. The genotype, IESV 92207 DL, was the superior genotypes in grain yield and yield related traits, although it was second in brix % and ethanol yield followed by E36-1. At phenotypic and genotypic levels, grain yield was positive and significant correlations with panicle weight and panicle width. There was positive and significant ($p < 0.01$) correlations between ethanol, juice, sugar and fresh stalk yields at both levels, this indicates the merits of these quality characters to improve ethanol yield.

Keywords: Brix; Ethanol; Sugar; Sweet sorghum; Genotypes; DAP fertilizer; Interactions; Urea

Introduction

The human society has been stimulated to develop renewable resources with a major concern for the security of oil supplement, threat of environmental contamination from use of fossil fuel, and alarming effect of the greenhouse gas emissions [1]. Bio-ethanol is one of the most common biofuels that can help to reduce environmental contamination associated with the use of fossil fuel. In general, bio-ethanol from agricultural raw materials has become popular as an alternative energy source to petroleum-based fuels because it is both renewable and environment friendly [2]. Bio-ethanol is often produced from fermentable plant tissue [3]. Sweet sorghum (*Sorghum bicolor* (L.) Moench), rich in fermentable plant sugars, can be considered as an important feedstock for bio-ethanol production [4]. High yielding bio-ethanol crops are needed as the demand for bio-ethanol increases while dependence on fossil fuels declines.

Fertilization is one of the most effective management strategies; although often the most expensive, that is practiced in order to attain high crop productivity [5]. An appropriate fertilization practice is important in obtaining high biomass yields of bioenergy crops and subsequently high biofuel yields. Increasing nitrogen (N) fertilization rate has been shown to increase yield of corn stover, cob biomass and bio-ethanol yields [6]. Fertilization is also used as a common agronomic management practice to increase soil nutrient levels [7]. The levels of soil nutrients can be decreased by harvesting crops over time without or improper fertilization [8]. Fertilization, however, not only can it affects crop biomass yields but also soil nutrient and soil microbial community [9].

The increasing bio-ethanol demand has stimulated research towards potential crop like sweet sorghum for bio-ethanol use. Unlike the traditional bio-ethanol producing crops such as maize (*Zea mays* L.) and sugarcane (*Saccharum* spp.), sweet sorghum has, recently, gained much attention for bio-ethanol production. Sweet sorghum has both readily fermentable sugar-based (i.e., sucrose, glucose, and fructose) and cellulosic-based (i.e., starch, hemicellulose, and cellulose) ethanol product [10]. There was a growing interest by the highly populated countries such as India and China to expand bio-ethanol industry using sweet sorghum feed. For example, the development of sweet sorghum is one of the main agricultural policy directions of China in promoting sustainable land use across semi-arid environments of the country. In general, sweet sorghum is globally set to become a priority commodity for numerous researches. However, the research towards major area of interventions, particularly on variety development and fertilization strategies, has been limited in Ethiopia. Therefore, the objective of this study was to evaluate the agronomic and quality traits of different sweet sorghum genotypes sown at two contrasting N and P fertilizer rates in the semi-arid conditions of Central Rift Valley (CRV) Ethiopia.

Materials and Methods

Description of the study sites

The field experiments were carried out during kiremt season in 2015 to 2016 at Melkassa (8°30'N, 39°21'E, 1550 m elevation) and Meisso (9°13'N, 40°45'E, 1400 m elevation) area in the CRV of Ethiopia. The climate of the CRV region is tropical and dry semi-arid. Melkassa and Meiso have a mono-modal and bi-modal rainfall pattern, with average annual rainfall of 763 mm and 470 mm, and average annual temperature of 21.3°C and 22.8°C, respectively. Melkassa soil is classified as Andosols, well-drained sandy loam, with an average pH of

7-8.2 while Meiso soil is primarily Vertisols, well-drained clay, with an average pH of 7-8.6.

Experimental design and field procedure

A factorial randomized complete block design with three replications was used to evaluate the performance of agronomic and quality traits of 15 sweet sorghum genotypes and effects of two fertilization treatments (with recommended fertilizers (RF) and without fertilizers (NF)), and their effect of interactions on sweet sorghum productions. Each plot had 4 rows of 5 m length with row spacing of 75 cm. Sowing were done in early July in both years and locations. Seeds were sown by hand drilling. Twenty days after planting the seedlings were thinned to 20 cm distance between plants. Phosphorus and nitrogen fertilizers were applied at the recommended rates of 100 kg ha⁻¹ and 50 kg ha⁻¹ in the form of DAP and Urea, respectively. The DAP was applied during planting in the seed furrow. All plots were top-dressed with Urea when the plants were 30 cm tall. The recommended fertilizers rates were chosen based on the Ethiopian Ministry of Agriculture and Natural Resource blanket recommendation for P and N for grain sorghum in Ethiopia. Two hand weeding were done at 20 and 40 days after sowing for effective weed control. λ -apholotrin (Karate) was sprayed twice to protect crop from stem borer. Other management practices were adopted as per recommendations of sorghum crop.

Data collection

From 2015 to 2016, data were collected on days to blooming (DB), days to flowering (DF), days to maturity (DM), plant height (PH) and brix % at soft dough stage (BRXS). At maturity, grain yield (YLD), and quality characters including fresh stalk yield (FSY) and brix% at hard dough stage (BRXH) were recorded over two locations. In 2016, the additional parameters were added and collected on grain yield components including panicle width (PWD), panicle length (PL), and panicle weight (PWT), and quality characters including ethanol yield (EY), dry stalk yield (DSY), juice yield (JY) and sugar yield (SY) were recorded at both locations.

For obtaining of fresh stalk yield, juice yield, yield of fermentable sugar and bio-ethanol yield from stalks, sweet sorghum plants were harvested at hard dough maturity stage. Brix percentage in juice were recorded using digital hand refractometer model HI 96801. Yield of fermentable sugars and potential ethanol yield per hectare were obtained using following formula

Yield of fermentable sugars (t ha⁻¹)=Juice yield (t ha⁻¹) × Brix percentage × 0.85

Potential ethanol yield (L ha⁻¹)=Juice yield (t ha⁻¹) × Brix percentage × 0.85/1.76

The juice was obtained using method computation based on Wortmann et al. [11]

CSY=(FSY-DSY) × Brix × 0.75; JY, 80% extracted=[FSY-(DSY-CSY)] × 0.8; SY=JY × Brix × 0.75.

Where CSY is conservative sugar yield (t ha⁻¹); FSY is fresh stalk yield (t ha⁻¹); DSY is dry stalk yield (t ha⁻¹); JY is juice yield (t ha⁻¹), and SY is sugar yield (t ha⁻¹).

Sugar concentration of juice is 75% of Brix expressed in g kg⁻¹ sugar juice. Brix percentage at hard dough stage was used for estimations of sugar and ethanol yield.

Statistical Analysis

Data were subjected to analysis using SAS ver. 9.1. The PROC GLM procedure was used in SAS in order to make inferences concerning genotype (G) and fertilization (F) across years and locations [12]. All factors (genotype, fertilizer, block, and environment) were treated as random variables. The phenotypic and genotypic correlation coefficients were calculated for every pair of traits using the PROCANDISC in sas procedure. To better explain the relationship between ethanol yield and other related traits, and grain yield and other yield related traits.

Results

The results of analysis of variance for the effects of G, F, E and their interactions G × F, G × E, G × F × E selected sweet sorghum agronomic and quality traits pooled across years and locations are presented in Tables 1 and 2, respectively. The combined means of treatments (with and without fertilizers), with recommended fertilization and without fertilization practices on agronomic and quality traits are shown in Tables 3 and 4, respectively. Phenotypic and genotypic correlations among the agronomic and quality characters are presented in Tables 5 and 6, respectively.

Analysis of variance

Mean of squares of all the characters studied, showed highly significant difference (P<0.01) among the tested sweet sorghum genotypes and environments. Environment, genotypes, environment × genotype and environment × genotype × fertilizer interaction effects were significant for all ethanol, grain and yield components. Mean of squares of fresh stalk yield, dry stalk yield, juice yield, sugar yield, ethanol yield plant height, days to 50% flowering, grain yield and panicle weight showed significant difference among the tested fertilization practices, however, brix (%) at soft and hard dough stage, DB, DM and PL had not significant responses with fertilizers (Tables 1 and 2).

Mean performance of genotypes and effect of fertilizers across the environments

The variation in ethanol yield due to fertilizer applications may be traced to the variation in fresh stalk sugar and juice yield attribute. Nitrogen and phosphorous fertilizations significantly increased fresh stalk yield, dry stalk yield, juice yield, fermentable sugar yield, ethanol yield, plant height, grain yield, panicle weight and days to 50% flowering over control, but brix (%) and other agronomic characters had not varied with fertilizations (Tables 1 and 2). Increase in ethanol yield due to fertilization in sweet sorghum genotypes was primarily due to increase in juice yield and sugar concentration. Genotypes E36-1, ICSR 93034, IESV 92207 DL and IESV 92008DL, produced greater estimated sugar and ethanol yield, which were the natural effect of brix (%), juice yield and stripped stalk weight.

Among the 15 sweet sorghum genotypes, S 35 and ICSB 654 genotypes had early blooming, flowering and maturity but they had low grain yield and panicle weight. The genotype IESV 92207 DL was superior to genotypes in grain yield and yield related traits but it had late blooming, flowering and maturity, while it was the second in sugar and ethanol yield flowed by E 36-1.

Source	df	2015-2016				2016			
		DB	DF	DM	PHT	YLD	PL	PWD	PWT
Genotype(G)	14	**	**	**	**	**	17.66**	1.07**	0.02**
Fertilizer(F)	1		*		**	*	0.71ns	0.04ns	0.07 *
Environment(E)	3(1)	**	**	**	**	**	188.9**	91.8**	0.01**
Replication/E	8(4)	**		*	*		0.78ns	1.56**	0.01ns
G*E	42(14)	**	**	*	**	**	4.67ns	1.38**	0.03**
F*E	3(1)	**	**			**	16.57ns	3.05**	0.00ns
G*F	14	*	*		**	**	2.84ns	0.47ns	0.02**
G*F*E	42(14)	*	**	**	**	**	3.09ns	0.74ns	0.03**
CV(%)		5.38	3.99	3.02	8.65	11.82	11	12.23	22.59
Error		13.31	9.12	12.56	153.25	5.46	4.47	0.43	0.01
SD			3.02	3.54	12.38	2.34	2.51	1.06	0.11
SE+		0.38	0.32	0.37	1.31	0.25	0.19	0.08	0.01

Table 1: Combined analysis of variance for agronomic parameters of sweet sorghum genotypes, effect of fertilization and interactions tested at Melkassa and Meisso, Ethiopia. **, * and ns: Significant at 1 and 5% probability levels, and non significant, respectively, Under degree of freedom numbers in () shows for characters (PL, PWD and PWT). DB=Days to blooming, DF=Days to 50% flowering, DM=Days to maturity, PHT=Plant height (cm), YLD=Yield (qt ha⁻¹), PWD=Panicle width (cm), PL=Panicle length (cm), PWT=Panicle weight (kg).

Source	df	2015-2016			2016			
		BRXS	BRXH	FSY	DSY	JUY	SUY	EUY
Genotype (G)	14	16.20**	46.56**	68.54**	22.70**	25564687.8**	161071.05**	53149.19**
Fertilizer(F)	1	9.65ns	4.81ns	54.17*	5.67**	7087356.1**	151699.17**	63854.04**
Environment(E)	3(1)	75.48**	797.05**	1044.79**	662.86**	68953852.5**	3472366.67**	1167830.01**
Replication/E	8(4)	1.89ns	3.80*	1.14ns	0.98ns	93387.3ns	2978.13ns	446.87ns
G*E	42(14)	14.23**	19.82**	62.32**	37.95**	21306986.6**	192607.67**	66348.73**
F*E	3(1)	3.05ns	4.11*	6.09ns	12.82**	26399225.1**	489014.86**	187221.57**
G*F	14	6.52**	6.89**	95.54**	69.84**	26138454.1**	230379.03**	74627.73**
G*F*E	42(14)	7.39**	10.34**	53.89**	51.73**	20956514.5**	181937.21**	58452.87**
CV(%)		12.70	11.99	26.24	11.55	11.07	11.87	9.58
Error		2.70	1.53	9.78	0.57	389129	3823.82	841.65
SD		1.01	1.01	0.97	4.3	2859.35	292.29	168.04
SE+		0.06	0.05	0.04	0.32	213.12	21.79	12.53

Table 2: Combined analysis of variance for quality parameters of sweet sorghum genotypes, effect of fertilization and interactions tested at Melkassa and Meisso, Ethiopia. **, * and ns: Significant at 1 and 5% probability levels, and non significant, respectively, Under degree of freedom numbers in () shows for characters (DRST, JUY, SUY and ETY). BRXS=Brix% at soft dough stage, BRXH=Brix% at hard dough stage, FSY=Fresh stalk yield (ton ha⁻¹), DRSY=Dry stalk yield (ton ha⁻¹), JUY=Juice yield (kg ha⁻¹), SUY=Sugar yield (kg ha⁻¹), ETY=Ethanol yield (L ha⁻¹).

Sweet sorghum genotypes	2015-2016					2016		
	DB	DF	DM	PHT	YLD	PL	PWD	PWT
Ent.#64DTN						18.42	5.29	0.39
IESV 92008DL						18.64	5.32	0.36
E 36-1						19.00	5.17	0.46
ICSR 93034					23.87	19.75	5.55	0.38
ICSB 324						21.13	4.86	0.32
IESV 92207 DL						19.92	5.85	0.40
IESV 92028 DL						18.74	5.44	0.39
104GRD		81.17				19.05	5.61	0.42
NTJ2						18.98	5.46	0.44
ICSB 654						22.43	4.83	0.37
IS2331						18.78	5.12	0.40
IESV 92099 ID						19.06	5.46	0.35
S 35						18.92	5.30	0.32
MRE22XIS8613/3/1/2/5-2-1						17.87	5.36	0.37
Gambella1107						17.68	5.85	0.38
Mean	67.83	75.67	110.72	143.19	19.77	19.22	5.36	0.38
LSD(5%)	2.09	1.72	2.02	7.04	1.37	1.7	0.53	0.07
Fertilizers(kg ha ⁻¹)								
RF	67.49	75.31	110.58	144.98	20.05	19.16	5.35	0.40
NF	68.18	76.03	110.83	141.41	19.49	19.29	5.38	0.36
Mean	67.83	75.67	110.72	143.19	19.77	19.22	5.36	0.38
LSD (5%)	ns	0.63	ns	2.57	0.5	ns	ns	0.03

Table 3: Combined means of sweet sorghum genotypes and effect of fertilization for agronomic traits at Melkassa and Meisso. ns=non significant, RF=with recommended fertilizers (100:50=DAP and Urea, respectively) and NF=without fertilizer. DB=Days to blooming, DF=Days to 50% flowering, DM=Days to maturity, PHT=Plant height (cm), YLD=Yield(qt ha⁻¹), PWD=Panicle width (cm), PL=Panicle length (cm), PWT=Panicle weight (kg).

Correlations

Correlation between agronomic characters

Phenotypic and genotypic correlations among the characters are presented (Table 5). Panicle weight and width and days to blooming were observed to have positive and significant correlations with grain yield at phenotypic and genotypic levels. On the other hand, grain yield had significant and negative correlation with days to maturity and panicle length at phenotypic correlation level. There was a significant and negative correlation between panicle length and panicle weight at both levels. Days to flowering had positive and significant correlations with days to maturity and blooming at both levels, days to flowering indicating that there was certain inherent relationship between these characters. Days to blooming had significant and

positive association with days to maturity, panicle weight and width at genotypic level, while it had significant and positive correlation with days to flowering and grain yield at both levels.

Correlation between quality characters

Phenotypic and genotypic correlations among the characters are presented (Table 2). At phenotypic and genotypic levels, were observed to have positive and highly significant ($p < 0.01$) correlations between juice, sugar, ethanol and stalk yield in Table 6. Brix percentage at hard dough maturity stage was highly significant ($p < 0.01$) and positive associated with sugar and ethanol yield at phenotypic correlation, but it had highly significant ($p < 0.01$) and negative associations with fresh and dry stalk yield.

Sweet sorghum genotypes	2015 - 2016			2016			
	BRXS	BRXH	FSY	DRSY	JUY	SUY	ETY
Ent.#64DTN				6.32	4491.10	319.65	190.61
IESV 92008DL				6.77	6157.70	629.83	365.93
E 36-1				6.56	6257.40	750.83	434.23
ICSR 93034				6.43	8293.50	621.21	371.90
ICSB 324				7.73	5483.30	517.90	300.90
IESV 92207 DL				7.45	8048.70	678.01	381.52
IESV 92028 DL				6.27	4879.70	472.44	285.23
104GRD				4.02	4351.50	451.57	261.42
NTJ2				7.20	5446.30	466.40	265.62
ICSB 654				3.33	3314.60	428.57	248.06
IS2331				8.53	4944.40	502.66	297.31
IESV 92099 ID				7.39	6166.40	584.91	341.84
S 35				6.59	5639.80	482.34	280.95
MRE22XIS8613/3/1/2/5-2-1				7.92	3713.00	369.14	209.36
Gambella1107				5.90	7322.70	538.99	307.55
Mean	12.94	10.31	11.93	6.56	5634.01	520.96	302.83
LSD (5%)	1.08	0.70	1.46	0.61	504.4	50	23.46
Fertilizers (kg ha ⁻¹)							
RF	12.75	10.43	12.30	6.74	5832.43	549.99	321.66
NF	13.13	10.19	11.54	6.38	5435.57	491.93	283.99
Mean	12.94	10.31	11.92	6.56	5634.00	520.96	302.83
LSD (5%)	ns	ns	0.53	0.22	184.18	18.23	8.57

Table 4: Combined means of sweet sorghum genotypes and effect of fertilization for quality traits at Melkassa and Meisso. ns=non significant, RF=with recommended fertilizers (100:50=DAP and Urea, respectively) and NF=without fertilizer. BRXS=Brix% at soft dough stage, BRXH=Brix % at hard dough stage, FSY=Fresh stalk yield (ton ha⁻¹), DRSY=Dry stalk yield (ton ha⁻¹), JUY=Juice yield (kg ha⁻¹), SUY=Sugar yield (kg ha⁻¹), ETY=Ethanol yield (L ha⁻¹).

Discussion

Mean performance of genotypes and effect of fertilizers across the environments

This study showed the quality characters of sweet sorghum genotypes were significantly more affected by interactions than agronomic characters. These results are in agreement with those obtained by Khaled. An increased of stalks yield, juice yield, fermentable sugar yield and ethanol yield, were recorded due to application of fertilizer over control (Table 4). These variations in yield and yield attributes due to fertilizer application may be traced to the variation in growth attributes. Increase in ethanol yield due to fertilizations in sweet sorghum genotypes was primarily due to increase in FSY, JUY and SUY. The results are in agreement with those

obtained by Ratnavathi et al. [13]. Sweet sorghum brix (%) both at soft and hard dough stages were not significantly affected by fertilizations. Soileau and Bradford reported that sweet sorghum brix do not consistently relate to applied N, P, and K fertilizers. At physiological maturity, brix (%) and sugar yield were maximized during the dough stage, which was in agreement with the results of Broad head [14]. In the present study, brix % at hard dough stage was lower than in soft dough stage for sweet sorghum genotypes might be subjected to some type of stress environment and planting time variability. The difference in stalk yield, juice yield, sugar yield and ethanol yield among the 15 genotypes were significant. Genotypes E 36-1, ICSR 93034, IESV 92207 DL and IESV 92008DL were superior to the tested genotypes in quality characters except brix (%) value. These genotypes produced greater estimated ethanol yield, which were the natural effect of juice yield, stalk weight and plant height. Accordingly, the highest sugar and

ethanol yields were recorded when the juice yield was the highest, whereas the lowest sugar and ethanol yields were obtained when juice yields were the lowest.

The grain yield, panicle weight, days to 50% flowering and plant height were significantly increased by fertilizations application over control, but the remaining agronomic characters had not varied with fertilizations (Table 3). Positive effect of fertilizers especially nitrogen on grain yield and yield attributes of sweet sorghum was reported by Hugar et al. [15].

The genotype IESV 92207 DL was superior to genotypes in grain yield and yield related traits, while it was the second in sugar and ethanol yield followed by E 36-1. In sub-Saharan Africa, these kinds of varieties were proposed to serve the small holder farmer to secure food and generate income. After physiological maturity (hard dough stage), the grain can be harvested and the stalk sold to the nearest distilleries as feedstock. Thus, farmers can be benefited from both the grain as well as the stalk. Sweet sorghum bagasse (after extraction of juice) can be used as animal feed without chemical or physical upgrading.

Traits	DB	DF	DM	PHT	YLD	PL	PWD	PWT
DB	1	0.79**	-0.01	0.09	0.29**	-0.27**	0.15	0.05
DF	0.97**	1	0.37**	0.13	-0.02	-0.11	-0.11	-0.01
DM	0.58*	0.63*	1	0.11	-0.60**	0.36**	-0.63**	-0.09
PHT	0.27	0.31	0.29	1	0.09	0.12	-0.01	0.27**
YLD	0.55*	0.47	0	0.36	1	-0.35**	0.63**	0.21**
PL	-0.45	-0.46	0	-0.13	-0.31	1	-0.22**	0.06
PWD	0.51*	0.43	0.05	0.35	0.51*	-0.60*	1	0.19*
PWT	0.51*	0.49	0.56*	0.35	0.53*	-0.34	0.36	1

Table 5: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among eight agronomic characters from 15 sweet sorghum genotypes. **, *: Significant at 1 and 5% probability levels, respectively, DB=Days to blooming, DF=Days to 50% flowering, DM=Days to maturity, PHT=Plant height (cm), YLD=Yield (qt ha⁻¹), PWD=Panicle width (cm), PL= Panicle length (cm), PWT=Panicle weight (kg).

Traits	BRXS	BRXH	FSY	DRSY	JUY	SUY	ETY
BRXS	1	-0.04	0.20*	0.23**	-0.02	-0.04	-0.03
BRXH	0.36	1	0.29**	-0.37**	0.07	0.53**	0.53**
FSY	-0.24	0	1	0.56**	0.52**	0.26**	0.25**
DRSY	0	0.35	0.24	1	-0.36**	-0.49**	-0.49**
JUY	-0.29	-0.26	0.85**	-0.3	1	0.84**	0.82**
SUY	0.04	0.49	0.69**	-0.06	0.68**	1	0.99**
ETY	0.02	0.49	0.67**	-0.08	0.67**	1**	1

Table 6: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among seven quality characters from 15 sweet sorghum genotypes **, *: Significant at 1 and 5% probability levels, respectively, BRXS=Brix% at soft dough stage, BRXH=Brix% at hard dough stage, FSY=Fresh stalk yield (ton ha⁻¹), DRSY=Dry stalk yield (ton ha⁻¹), JUY=Juice yield (kg ha⁻¹), SUY=Sugar yield (kg ha⁻¹), ETY=Ethanol yield (L ha⁻¹).

Correlation between agronomic characters

Phenotypic and genotypic correlations among the characters are presented (Table 5). Panicle weight and width and days to blooming were observed to have positive and significant correlations with grain yield at phenotypic and genotypic levels, showing that these traits were inter-related. Similar results were reported by Tesfaye et al. [16] that the grain yield was positive and significantly associated with panicle weight and width among 200 sorghum accessions studied. On the other hand, grain yield had significant and negative correlation with days to maturity and panicle length at phenotypic correlation level. Similarly, Patted et al. [17] reported days to maturity expressed

significant negative correlation with grain yield at phenotypic and genotypic levels. These negative correlations help to select the early maturing genotypes with high grain yield at moisture stressed area. There was a significant and negative correlation between panicle length and panicle weight at both levels.

Days to flowering had positive and significant correlations with days to maturity and blooming at both levels, days to flowering indicating that there was certain inherent relationship between these characters. Days to blooming had significant and positive association with days to maturity, panicle weight and width at genotypic level, while it had

significant and positive correlation with days to flowering and grain yield at both levels.

Correlation between quality characters

At phenotypic and genotypic levels, were observed to have positive and highly significant ($p < 0.01$) correlations between juice, sugar, ethanol and stalk yield. It was observed from the both correlations, that it is practicable to suggest direct selection to increase the ethanol production from the traits juice and stalk yield which are easily measurable. The observation of its positive and highly significance ($p < 0.01$) correlation the general notion that the traits are direct related; and suggests that breeding for higher juicing and biomass type genotypes might result in high ethanol yield and sugar yield than other traits. This study was in agreement with the results of Makanda and Brix percentage at hard dough maturity stage was highly significant ($p < 0.01$) and positive associated with sugar, ethanol and fresh stalk yield at phenotypic correlation. These results agreed with Patel et al. [18] reported that significant positive correlation among brix and fresh stalk yield.

Conclusion

This study has clearly brought about the importance of fertilizer and genotype in influencing the grain and ethanol yield components in sweet sorghum. In Sweet sorghum, quality components varied with genotypes, fertilizers, environments and their interactions, however, brix was not significantly affected by fertilizations. An appropriate fertilizer application is an important management practice to increase soil nutrient levels in obtaining high biomass yields of bioenergy crops and subsequently high biofuels and grain yield. Generally, the genotypes included here were meant to have dual purposes (for grain as well as for bio ethanol). At hard dough stage, sweet sorghum can produced grain yield from 12 to 25 qt ha⁻¹ that have an added advantage than at soft dough stage harvest for sugar and ethanol production.

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