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Evaluation of Sweet Sorghum (*Sorghum bicolor* L. Moench) Genotypes for Agronomic Traits, Stalk Yield and Brix Value in Central Rift Valley of Ethiopia

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ABSTRACT

Thirty (30) Sweet Sorghum genotypes were evaluated for 8 traits in a Randomized Complete Block Design (RCBD) with three replications at Melkassa Agricultural Research Center in 2018. The objective of the study were to develop best performed sweet sorghum genotypes that adapted to central rift valley area of Ethiopia and to identify best performed genotypes for agronomic traits, stalk yield and brix value. The analysis of variance showed that mean square of sweet sorghum genotypes was highly significant (p<0.01) for all traits studied. The analysis of variances of sweet sorghum genotypes evaluated for 8 traits revealed highly significant difference between the genotypes for most traits and significant difference among genotypes for days to heading. It was interesting to note that there were eight genotypes matured before the check while genotype MR#22XIS8613/2/3-1-3 was the late maturing with 133 days. Genotype Ent.#64DTN shown to head and mature early in both characters. In case of plant height, twelve genotypes were found to be taller than the check. Genotype IESV 91104 DL was taller than other all genotypes with the height 215cm. In sweet sorghum, tall and thick stems contribute more towards the millable cane yield and juice yield. There were twelve genotypes have brix values greater than 18% before grain filling while only ten genotypes scored greater than 18% at maturity stage. The genotype, IESV 92001 DL, was the superior genotype in brix values before grain filling and ICSB 654 also revealed highest in brix value at physiological maturity. The most important genotypes for showing excellent performance on grain yield per hectare obtained from IESV 92008DL, MR # 22XIS8613/2/3-1-3 and IS 2331with grain yield of 2791 kg/ha, 3416 kg/ha and 2677 kg/ha respectively, than the check variety (2530 kilogram per hectare).

INTRODUCTION

Agriculture is the backbone of the Ethiopian economy. This particular sector determines the growth of all other sectors and consequently the whole national economy. It constitutes over 50% of the gross domestic product (GDP), accounts for over 85% of the labour force and earns over 90% of the foreign exchange. On average, crop production makes up 60% of the sector's outputs, whereas livestock accounts for 27% and other areas contribute 13% of the total agricultural value added. The sector is dominated by small-scale farmers who practice rain-fed mixed farming by employing traditional technology, adopting a low-input and low-output production system. The land tilled by the Ethiopian small-scale farmer accounts for 95% of the total area under agricultural use, and these farmers are responsible for more than 90% of the total agricultural output (Diriba Welteji 2018).

The primary source of energy in Ethiopia is biomass, which accounts for 91% of energy consumed, Petroleum supplies about 7% of total primary energy and electricity accounts for only 2% of total energy use. Biomass consumption accounts for over 98% of total supply in the residential sector. The World Development Indicators and many other studies show that the national energy balance is dominated by a heavy reliance on firewood, crop residues, and dung. Due to the dependence on biomass for cooking, CO2 emissions in Ethiopia have increased from 5.1 million tons in 2005 to 6.5 million tons in 2010. On a per capita basis, this amounts to 0.06 tons of CO2 in 2005, 0.075 tons in 2010, and 0.19 tons in 2014. (Md Alam Hossain Mondal et al. 2018).

Bioethanol is one such dominant global renewable transport biofuel which can readily substitute fossil fuels. Conventionally, bioethanol has been produced from sucrose and starch rich feedstocks (edible agricultural crops and products) known as 1st generation bioethanol; however this substrate conflicts with food and feed production. As an alternative to 1st generation bioethanol, currently there is much focus on advancing a cellulosic bioethanol concept that utilizes lignocellulosic residues from agricultural crops and residues such as bagasse, straw, stover, stems, leaves and deoiled seed residues (Almodares, A. and Hadi, M.R. 2009).

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, bioethanol from agricultural raw materials has become popular as an alternative energy source to petroleum-based fuels because it is both renewable and environment friendly (Chalachew and Rebuma, 2018).

Sweet sorghum [*Sorghum bicolor* (L.) Moench], a C4 Graminaceous crop which has sugar-rich stalks and which is a water-use efficient crop has a very good potential as an alternative feed stock for ethanol production. It is the only crop that provides grain and stem that can be used for sugar, alcohol, syrup, jaggery, fodder, fuel, bedding, roofing, fencing, paper and chewing (C. V. Ratnavathi 2011).

Sweet sorghum can be used as a feedstock for ethanol production because, it has higher tolerance to salt and drought comparing to sugarcane and corn that are currently used for biofuel production. In addition, high carbohydrates content and high fermentable sugar content in sweet sorghum stalk makes it to be more suitable for fermentation to ethanol. Therefore, it is suggested to plant sweet sorghum for biofuel production in hot and dry countries to solve problems such as increasing the octane of gasoline and to reduce greenhouse gases and gasoline imports (Almodares, A. and Hadi, M.R. 2009).

The government of Ethiopia is promoting bioethanol for house hold cooking to save forests and maintain soil fertility. Sweet sorghum is also being considered as potential feedstock for bioethanol processing. Therefore, the objective of this study was to evaluate sweet sorghum genotypes for agronomic traits, brix value and stalk yield in the Central Rift Valley of Ethiopia.

MATERIALS AND METHODS

The experiment was conducted during the July to October rainy season of 2018 at Melkassa Agricultural Research Center. The Center is located 17 km southeast of Adama in the semi-arid region of the Central Rift Valley of Ethiopia at 8^{o} 24'N latitude and 39^{o} 12'E longitude and Its elevation is 1550 meter above sea level (m.a.s.l.). The site receives 763 mm mean annual rainfall. The area has a mean maximum and minimum annual temperature of 34°C and 19°C and monthly temperature of 38.06°C and 21.06°C during main season, respectively. Melkassa soil is classified as Andosols, well-drained sandy loam, with an average pH of 7-8.2.

The experiment was carried out in Randomized Complete Block Design consisted of 30 Sweet Sorghum genotypes sown in three replications. The plot was plowed twice and disc harrowed using Tractor. Ridges were made at 75 cm between rows and seeds were drilled and thinned to 15 cm spacing. Plot size was 3.2 meters wide and 5 meters long. Seed rate was 10 kg/ha and fertilizer was applied at the rate of 100 kg/ha DAP and 50 kg/ha Urea. DAP fertilizer was applied during planting and UREA was at the four leaf stage and other agronomic practices were applied for each treatments.

Observations were recorded for Days to flowering, (the number of days from planting to 50% heading) while Days to maturity was recorded the number of days from planting to 85% physiological maturity for each genotype in each plot by checking the maturity of seed from sample plants), Plant height (measured at physiological maturity from the soil surface to the top of the head from randomly selected plants), Brix value was recoded as refractometer reading at dough stage and grain maturity. The samples were weighed wet, oven-dried, and weighed dry to determine the water content after correcting for leaf weight.

Juice and sugar yield were calculated in three steps:

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 (Mg ha−1), FSY is fresh stalk yield (Mg ha−1), DSY is dry stalk yield (Mg ha−1), JY is juice yield (Mg ha−1), and SY is sugar yield (Mg ha−1). Sugar concentration of juice is 75% of Brix expressed in g kg−1 sugar juice.

Stalk yield was recorded as the weight of stalks from the central two rows. Grain yield (measured in gram for each plot of each entry from central rows and then converted to kilogram per hectare for analysis),

RESULTS AND DISCUSSIONS

Days to Heading, Maturity and Plant Height

Mean square of the 8 characters from analysis of variance (ANOVA) at Melkassa is presented in (Table 1). Analysis of variance showed that there was highly significance difference ($P \leq 0.01$) among the sweet sorghum genotypes for days to heading, days to maturity and plant height (Table 2). The mean value for days to heading ranged from 74 to 94 days after sowing (das) with an average value of 83 days. There were seven genotypes (Ent.#64DTN, E 36-1, IESV 94021 DL, ICSR 93034, IESV 91104 DL, IESV 92028 DL and S 35) headed before the local check.

Similar to days to heading, twenty genotypes were early maturing genotypes ranges from 106 to 122 days. The mean number of days to maturity was 120.(Table 2). There were eight genotypes matured before the check while genotype MR#22XIS8613/2/3-1-3 was the late maturing with 133 days. Genotype Ent.#64DTN shown to head and mature early in both characters. In case of plant height, twelve genotypes were found to be taller than the check. The range of plant height was 136 to 215 cm with a mean of 170cm. Genotype IESV 91104 DL was taller than other all genotypes with the height 215cm. In sweet sorghum, tall and thick stems contribute more towards the millable cane yield and juice yield was reported by Sandeep Singh Tomar et al. (2012).

Brix Value

Brix value was determined using refractometer at dough and physiological maturity stages. The Brix value was generally high during dough stage and a little lower during maturity. Then range of brix value was 13.9-23.1 at the dough stage and 15.1-23.0 during maturity. If the values on dough are considered then twelve genotypes have brix values greater than 18% before grain filling while only ten genotypes scored greater than 18% at maturity stage. The genotype, IESV 92001 DL, was the superior genotype in brix values before grain filling and ICSB 654 also revealed highest in brix value at physiological maturity. This shows that as the crop matures the sugar content in the stalk decreases as the sugar is translocated to the sink. Brix values as high 23.1% was recorded at the dough stage. The sugar content in the juice of sweet sorghum varies in different varieties (Almodares et al., 1994a). The Brix range in different varieties of sweet sorghum is 14.32-22.85% (Table 2) was reported by (Almodares and Sepahi, 1996). High brix is essential for maximizing the amount of sucrose and ethanol produced per unit area cultivated was also reported by Sandeep Singh Tomar et al. (2012). Compared to grain sorghum, sweet sorghums feature more rapid growth, higher biomass production, wider adaptation, and have greater potential for ethanol production (Reddy *et al*., 2007).

Number of Tiller, Stalk Yield and Grain Yield

The range of number of tillers was 1.4 to 5.2 with a mean of 3. There were twenty two genotypes shown large number of tillers than local check. Main stems with less or no tillers became prone to lodging. Removal of tillers results in decreased number of stalks per hectare, resulting in the reduction of the economic yield.

Almost all genotypes of sweet sorghum showed higher stalk yield than local check. The range of stalk yield was 10 to 27 ton/ha with a mean of 18 ton/ha (table 2). This is approximately 1852 to 5000 liters of bioethanol per hectare assuming that 54 kg of sweet sorghum results to one liter of bioethanol. The stalk is a value addition to the primary product of grain production. However this includes processing, transportation and overhead cost but one can assume that it can be an excellent feedstock for a Bioethanol Micro Distiller Enterprise. Farmers in Ethiopia use the stalk for various purposes but its value has never been studied. Farmers usually use it as fire wood, livestock feed or temporary construction of huts.

Grain yield is the important component of plant performance under a set of growing conditions. Any physiological or agronomic parameter at a given stage of growth would be of further use only when its effect is reflected on yield either way. Grain yield is a function of HI and dry matter production (Ludlow and Muchow, 1990).

There were three genotypes IESV 92008DL, MR # 22XIS8613/2/3-1-3 and IS 2331 were found significantly superior over local checks with grain yield of 2791 kg/ha, 3416 kg/ha and 2677 kg/ha respectively. The range of grain yield was 1090 to 3416 kg/ha with a mean of 1971 kg/ha.

Table 1: ANOVA

		Mean square							
Source of variation	df	DH	DM	PH	BBGF	BAGF	NT	SY	GY
REP	2	8.7	19.3	11.2	8.6	3.9	4.1	14.9591	258082
TRT	29	54.2	131.1	997.2	10.5	6.5	1.9	32.797	680020
ERROR	58	13.5	5.4	102.5	2.7	1.6	0.3	4.4403	116068
CV		4.4	1.9	6.0	9.3	7.1	17.4	12.0	17.3
LSD(@ 0.05)		**	**	**	**	**	**	**	**

- Sig @ 0.05 probability level

Key:

- DF- Days to Heading
- DM- Days to Maturity
- PH- Plant Height
- BAGF-Brix Value after grain filling
- BBGF- Brix value before grain filling
- NT- number of tillers
- SY- Stalk Yield
- GY-G rain Yield

Table 2. Agronomic Characteristics of 30 Sweet Sorghum Genotypes grown at Melkassa during 2018.

Trt	Genotypes	DH	DM	PH	BBGF	BAGF	NT	SY	GY
1	Ent.#64DTN	74.7j	105.7j	177.9c-g	19.5bc	17.5d-h	2.7e-i	21.3bc	2033.3d-i
2	IESV 92008DL	94.0a	125.3bcd	157.6h-l	16.8d-i	18.3c-f	1.9jkl	23.2b	2791.0b
3	E 36-1	78.7f-j	106.3j	163.5g-k	19.0b-e	18.9bcd	2.1h-l	20.5b-e	1476.0jkl
4	Local check	81.3c-h	124.3cd	172.5d-h	15.5hij	16.0ghi	2.5g-j	13.5j	2529.7bcd
5	MR # 22XIS8613/2/3-1-3	83.3b-g	133.7a	184.9b-e	20.3b	15.1i	4.1b	27.3a	3416.0a
6	IS 2331	86.7bc	124.7cd	184.5b-e	16.7e-i	17.5d-h	3.8bcd	17.2e-i	2677.3bc
7	SPV 422	86.0bcd	120.0ef	188.0bcd	16.0g-j	17.1d-i	2.6f-j	20.4b-f	1351.7kl
8	MR #22XIS8613/1/2/5-2-1	85.7bcd	119.3ef	190.1bc	14.3ij	17.5d-h	3.0d-g	17.3e-i	1781.7f-k
9	IESV 92008DL	81.0c-h	119.0ef	136.1n	16.8d-i	17.3d-h	3.8bcd	15.5g-j	2003.3d-j
10	Gambella 1107	86.3bcd	124.3cd	164.5g-j	18.8b-e	15.8hi	3.9bc	10.0k	1710.0h-k
11	ICSV 93046	85.3bcd	121.7de	196.3b	15.3hij	16.6e-i	3.1c-g	18.6c-g	1684.0h-k
12	IESV 94021 DL	76.3hij	113.0gh	170.3e-i	16.5e-j	17.7c-h	3.4b-f	17.9c-h	1551.0i-l
13	IESV 92165 DL	84.3b-f	129.0b	139.3mn	16.2f-j	17.7c-h	2.5g-j	20.9bcd	2025.3d-j
14	ICSR 93034	78.3g-j	118.3ef	196.5b	18.5b-g	16.8e-i	3.5b-e	16.4g-j	1591.3i-l
15	ICSB 324	86.7bc	125.3bcd	158.7h-l	17.3c-h	18.3c-f	1.4l	15.5g-j	2304.3b-g
16	IESV 92207 DL	87.7b	124.7cd	182.7b-f	19.3bcd	20.4b	3.0d-g	17.1e-i	1851.7f-k
17	Kari Mtama 1	81.7c-h	122.0de	184.1b-e	18.5b-g	17.0d-i	5.2a	17.0f-i	1823.3f-k
18	IESV 91104 DL	79.3e-j	112.3hi	215.0a	13.9j	18.4b-f	2.0i-l	17.7d-i	1819.3f-k
19	IESV 92028 DL	76.3hij	111.7hi	155.6i-m	17.7c-h	19.8bc	3.2c-g	22.2b	1686.3h-k
20	IESV 92021 DL	82.0b-h	116.7fg	162.3g-l	17.3c-h	18.5b-e	3.8bcd	14.4ij	1730.0h-k
21	104GRD	81.3c-h	127.0bc	155.0i-m	17.0c-h	17.0d-i	2.8e-i	14.8hij	1685.0h-k
22	NTJ2	86.0bcd	119.3ef	182.0b-f	17.0c-h	16.4f-i	1.6kl	17.8d-i	1618.3i-l
23	89MW 5073	84.7b-e	119.7ef	146.5lmn	17.8b-h	17.6d-h	3.1c-g	15.8g-j	1970.0e-j
24	IESV 92001 DL	86.3bcd	117.7f	147.8k-n	23.1a	18.0c-g	2.9e-h	17.5d-i	2216.7c-h
25	ICSB 654	80.7d-i	122.0de	176.1c-g	18.5b-g	23.0a	2.4g-k	17.7d-i	1971.3e-j
26	SDSL 90167	81.7c-h	128.0bc	164.0g-k	18.7b-f	17.3d-h	2.7e-i	18.0c-h	2317.7b-f
27	S 35	75.0ij	108.7ij	153.0j-m	19.0b-e	18.3c-f	3.2b-g	15.8g-j	1750.0g-k
28	Meko	81.3c-h	120.0ef	166.3f-j	16.5e-j	17.1d-i	3.2c-g	15.1hij	2511.3b-e
29	IESV 92099 ID	83.7b-g	117.3f	161.3g-l	19.5bc	17.6d-h	3.2c-g	15.4g-j	1090.0l
30	ICSV 700	81.3c-h	116.3fg	162.3g-l	16.5e-j	16.9d-i	3.0d-g	14.7hij	2185.0c-h
	Mean	82.6	119.8	169.8	17.6	17.7	3.0	17.5	1971.7
	CV	4.4	1.9	6.0	9.3	7.1	17.4	12.0	17.3
	LSD(@ 0.05)	5.9	3.8	16.5	2.7	2.1	0.8	3.4	556.8

DH= Days to Heading, DM= Days to Maturity, PH= Plant Height, BBGF= Brix value Before Grain Filling, BAGF= Brix value After Grain Filling, NT= Number of Tillers, SY= Stalk Yield, GY= Grain Yield.

Correlation coefficients

Correlation coefficient for different traits present in Table 3. Days to heading showed positive and highly significant correlation with days to maturity, plant height, brix value before maturity and Grain yield. However, this trait revealed negative and highly significant association with brix value at maturity and also non-significant correlation with the rest of the traits. Days to maturity displayed positive and highly significant correlation with plant height and stalk yield. Whereas negative and highly significant association with brix value at maturity and positive non-significant correlation with number of tillers and grain yield. However, this trait is negative and non-significant correlation with brix value before maturity. Plant height showed positive and highly significant association with grain yield and negative and significant correlation with brix value before maturity and also non-significant correlation with the rest of the traits. Brix value before maturity showed positive and highly significant association with stalk yield. While positive and non-significant correlation was found with the rest of traits.

Brix value at maturity showed negative and highly significant association with grain yield and however, positive and significant associations with stalk yield. Number of tillers showed negative and non- significant correlation with stalk yield and grain yield. Generally, stalk yield per hectare showed positive and significant correlation with grain yield.

Table 3: Pearson's Correlation Coefficient among different traits of Sweet Sorghum genotypes

	DH	DM	PLH	BBM	BAM	NT	SY
DM	0.4785**						
PLH	0.5804**	0.5122**					
BBM	0.4453**	-0.0097	-0.371*				
BAM	-0.5781**	-0.4854**	0.0069	0.1815			
NT	-0.1656	0.1143	-0.0677	0.2066	-0.0248		
SY	0.0491	0.5699**	0.1359	0.6141**	0.4916**	-0.2701	
GY	0.3723*	0.2585	0.6711**	0.0763	-0.5518**	-0.0057	0.3554*

CONCLUSION

Based on this study the performance of sweet sorghum genotypes evaluated for their traits revealed highly significant difference between the genotypes for most traits and significant difference among genotypes were observed. In current results twelve genotypes have brix values greater than 18% before grain filling while only ten genotypes scored greater than 18% at maturity. In addition these genotypes IESV 92001 DL, MR # 22XIS8613/2/3-1-3 at dough stage and ICSB 654, IESV 92207 DL at physiological maturity were superior genotypes in brix values respectively.
Among the studied genotypes the highest mean of grain yield/ha obtained from IESV 92008DL, MR#22XIS8613/2/3-1-3 and IS 2331 were the most important genotypes for showing excellent performance on grain yield per hectare 2791 kg/ha, 3416 kg/ha and 2677 kg/ha respectively than the check variety (2530 kilogram per hectare). Therefore, the availability of high yielding genotypes both in brix value and grain yield might be promising for the development of tall and thick stem genotypes for maximum ethanol production that could be exploited in future sweet sorghum breeding in the central rift valley.

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