American Journal of Biological and Environmental Statistics
2015; 1(1): 38-45
Published online June 30, 2015 (http://www.sciencepublishinggroup.com/j/ajbes)
doi: 10.11648/j.ajbes.20150101.15

Food Security Evaluation of Grain and Sugar Yields of Improved Sweet Sorghum Varieties for Sustainable Renewable Energy Supply Using Matrix Correlation

Vishwa Nath Maurya[1, *], Bijay Singh[2], Swammy Vashist[3], Charanjeet Singh Arneja[4], Ghebrebrhan Ogubazghi[5], Kamlesh Kumar Shukla[6]

[1]Department of Applied Mathematics and Statistics, School of Science & Technology, The University of Fiji, Lautoka, Fiji Islands
[2]Department of Soil Sciences, Punjab Agricultural University, Ludhiana, India
[3]Department of Accounting & Finance, Dilla University, Gedeo, Ethiopia
[4]Department of Agricultural Extension, Punjab Agricultural University, Ludhiana, India
[5]Department of Earth Science, Eritrea Institute of Technology, Asmara, Eritrea
[6]Department of Management, Adama Science and Technology University, Adama, Ethiopia

Email address:
prof.drvnmaurya@gmail.com (V. N. Maurya), prof_vnmaurya@yahoo.in (V. N. Maurya)

To cite this article:
Vishwa Nath Maurya, Bijay Singh, Swammy Vashist, Charanjeet Singh Arneja, Ghebrebrhan Ogubazghi, Kamlesh Kumar Shukla. Food Security Evaluation of Grain and Sugar Yields of Improved Sweet Sorghum Varieties for Sustainable Renewable Energy Supply Using Matrix Correlation. *American Journal of Biological and Environmental Statistics*. Vol. 1, No. 1, 2015, pp. 38-45. doi: 10.11648/j.ajbes.20150101.15

Abstract: Present paper aims to food security evaluation of grain and sugar yields of improved sweet sorghum varieties for sustainable renewable energy supply using matrix correlation. As part of research towards ensuring food security and ethanol production for sustainable renewable energy supply in Ghana, field trials were conducted to evaluate the grain yield, brix percentage (sugar content) yield and other agronomic parameters of eighteen (18) improved sweet sorghum lines and two local varieties in the Guinea-Savanna zone of Ghana, where the crop is mainly grown as a staple. The improved sorghum varieties were obtained from the International Crops Research Institute for the Semi –Arid Tropics (ICRISAT), India; Ethiopia, France, and Institute for Energy Research (IER), Mali and Nicaragua whereas the local varieties were obtained from the Savanna Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR), Ghana. The grain yield ranged between 50 - 632 kg/ha. Two sorghum varieties, ICSR 93034 and 104 GRD had the best grain yield. Generally, the brix percentage of stalk juice were between (6.2 – 21.4 %) and ten (10) improved sweet sorghum lines 35127-1-1, 36461-2, IS 23525, IS 23541, IS 23555, IS 23562, IS 23563, IS 23566-1, IS 23566-2 and IS 23574 recorded the best stalk yield and brix % (sugar content) throughout the physiological stages of growth. Generally the sugar content in the stalk juice was lower at the early, mid and late booting stages of physiological growth but increased steadily at the flowering stage and highest during the hard dough stage. On the other hand, the sorghum lines, IS 23562 and IS 23574 showed outstanding performances in terms of both grain and sugar yield and could be suitable varieties for dual-purpose. More also there was correlation ($p < 0.05$) between all traits measured. It is therefore, concluded that marker-assisted selection could be used to breed for sweet sorghum cultivars in the savannah agro-ecological zones of Northern Ghana to improve grain yields and bio-fuel production.

Keywords: Food Security, Brix Percentage, Ethanol, Sweet Sorghum, Sugarcane, Genetic Variation, Renewable Energy, Matrix Correlation

1. Introduction

Sorghum (*Sorghum bicolor L. Moench*) is a herbaceous annual grass of tropical origin that is cultivated as grain crop. It is characterized as a C4 crop with high photosynthetic efficiency and can be grown in tropical, subtropical, temperate, and semi-arid regions of the world (Shoemaker and Bransby, 2010). Sorghum is a primary staple food crop in the semi-arid tropics of Asia, Africa, and South America. The grain is normally used as food and animal fodder, but recently it has been used as raw material for the production of chemicals, such as levulinic acid (Ganjyal *et al*., 2007). Sweet sorghum is similar to grain sorghum that can grow to a height of more than 2 m with sugar-rich stalks. Sweet sorghum is a multipurpose crop due to its capacity to provide renewable energy products, industrial commodities, and food and animal feed. It is the only crop that provides grain for food, and stem that can be used for sugar, fuel, bedding, roofing, fencing, and paper production. The crop has been used for nearly 150 years to produce concentrated syrup with a distinctive flavour (Schaffert, 1992) whereas the stalk juice are rich in sugars and can be used to produce up to 7000 L of ethanol/ha (Seetharam, 2005). Sweet sorghum is closely related to sugarcane (Tarpley and Vietor, 2007) and can be used as substitute for sugarcane since the crop has an extensive genetic variation, including drought and heat tolerant varieties, which would enable the usage of marginal land that is not suitable for sugarcane cultivation. In addition, the gestation period of sorghum is shorter (3-5 months) compared to that of sugarcane (12-18 months) as reported by Amukelani and Wolfgang (2010). Due to the great capability of sweet sorghum in ensuring world food security as well combating the world fuel energy crisis and its potential to aid development in semi-arid regions, more attention has been paid to the crop by breeders in recent years (Amukelani and Wolfgang, 2010). Recent research work carried out by Arneja CS et al. [2], Maurya V.N. et al.[5,6,7,8] in different allied versions are also worth mentioning.

For this reason, improve sweet sorghum lines with dual-purpose were developed through international collaborative research. However, the performance of these varieties needs to be assessed in the growing regions for adoption by farmers.

1.1. Objectives of the Present Study

The objective of the study was to evaluate and identify the best sweet sorghum lines in terms of high grain yield and brix (sugar) percentage of stalk juice within the Guinea –Savanna zone of Ghana, where the crop is popularly grown for food.

1.2. Materials and Methods

The trial was carried out at the experimental field of the Savanna Agriculture Research Institute (SARI), Nyankpala (latitude 9˚25″N, longitude 0˚58″W and at an altitude of 183m above sea level) in the Northern Region of Ghana. The area falls within the Guinea Savanna zone (SARI, 2004).

The origin and descriptions of the eighteen (18) introduced lines and two (2) local sweet sorghum varieties have being shown in (Table – 1).

Table 1. *The Twenty sweet sorghum genotype tested in the field at CSIR-SARI 2012.*

	Entry name	Description	Origin
1	00-SB-F5DT-427	A breeding line of the tan plant type with white grain and medium height	IER, Mali
2	35127-1-1	A breeding line with tan plant type and white grain. The plant is quite tall	
3	35127-1-2	A breeding line with tan plant type and white grain. The plant is quite tall	
4	36461-2	A breeding line with tan plant type and white grain. The plant is quite tall	ICRISAT, India
5	ICSR 93034	A breeding line with tan plant type and white grain. The plant is quite tall	
6	104 GRD	A breeding line with pigmented plant type and red grain colour	
7	Faux Coludo Nevado	A breeding line with pigmented plant type and red grain colour	
8	447(471)496	A breeding line with pigmented plant type of medium height, the grain colour is white.	CIRAD, France
9	IS 23519	A landrace with pigmented plant type and red grain colour.	
10	IS 23525	A landrace of the tan plant type with white grain and of medium height.	
11	IS 23555	A landrace of the pigmented plant type with white grain and of medium height.	
12	IS 23566-2	A landrace of the pigmented plant type with white grain and quite tall.	
13	IS 23574	A landrace with pigmented plant type and red grain colour	Ethiopia
14	IS 23541	A landrace with tan plant type, white grain and quite tall	
15	IS 23562	A landrace with tan plant type and white grain. The plant is quite tall	
16	IS 23566-1	A landrace of the pigmented plant type with white grain and of medium height	
17	IS 23563	A breeding line with tan plant type and white grain. The plant is quite tall	
18	Sorgo Ligero	A breeding line of the tan plant type with white grain and of medium height.	Nicaragua
19	Kapaala	A commercial variety of tan plant type, medium height and white grain colour.	CSIR-SARI,
20	Dorado	A commercial variety of tan plant type, quite short in height with white in red glumes	Ghana

The experiment was laid out in an alpha design with 20 entries and three (3) replications. In each replication, there were 20 plots with each plot measuring 2 m x 1.2 m (2.4 m^2) and 1m between adjacent plots. Planting spaces of 75 cm between rows and 15 cm within row was used.

The 20 sweet sorghum lines were randomly assigned to the plots and approximately 6-8 seeds of each line were sown per hill. Two weeks after planting (2 WAP), the seedlings were thinned to three (3) plants per hill given a total plant population of 54 plants $plot^{-1}$. Immediately after sowing, pre-emergence weedicide, Roundup (i.e., glyphosate) was applied according to the manufacturer's manual and additional weeding was done manually using a hoe at 5 WAP. Four (4) and nine (9) weeks after planting, NPK 15-15-15 fertilizer was applied at the rate of 60 g $plot^{-1}$ and 15 WAP respectively whereas sulphate of ammonia (60 g $plot^{-1}$) was also applied as top dressing to meet the crops' total nitrogen requirement.

Data collected include Days to 50 % flowering where the plants were monitored daily and the number of days taken in each plot for 50 % of the plants to flower was recorded.

For Striped stalk yield (kg/ha) three (3) plants were randomly selected from each plot at flowering, soft dough and hard dough stages of growth for the determinations. The selected plants from each plot at each of the physiological stages were harvested from the base and leaves and leaf sheaths were removed. The striped stalks were then weighed separately and the average computed for each plot.

Panicle weight involved harvesting all panicles with grains at the physiological maturity (hard dough stage) and weighed. The average panicle yield for each plot was determined by dividing the total weight by the number of panicles for each plot.

Grain yields were determined by threshing and weighing all harvested panicles.

2. Juice Extraction and Sugar Content Determination

Three (3) plants per plot were randomly selected and harvested at six physiological stages – early booting (EB), mid booting (MB), late booting (LB), flower (FL), soft dough (SD) and hard dough (HD) stages for juice extraction and sugar content analysis. These stalks were weighed separately, pealed, crashed and squeezed to extract the juice. The sugar contents of juice collected were determined by digital hand saccharometer /refractometer (Atago type). The average sugar percentage of stalk juice was calculated for each plot.

3. Data Analysis

Data gathered was subjected to analysis of variance (ANOVA) using GENSTAT Discovery statistical software (Fourth Edition). Where significant differences were found, means were separated using the least significant difference (LSD) at 5% level of significance.

4. Results and Discussions

4.1. Days to 50 % Flowering

The number of days to 50 % booting were slightly different ($p < 0.05$) among the twenty (20) sweet sorghum lines as shown in [Figure 1].The Days to 50 % flowering ranged between 124 and 135 days with an average of 129 days. Two of the Sweet sorghum lines 447(471)496 and IS 23519 had the least number of days to 50 % booting while 36461-2, and IS 23555 recorded the highest days to 50 % booting. However, ten (10) improved sweet sorghum varieties (00-SB-F5DT-427, 104 GRD, 447(471)496, Coludo Nevado, ICSR 93034, IS 23519, IS 23525, IS 23562, IS 23574 , Sorgo Ligero, and the two control varieites (Kapaala, and Dorado) were below the average days to 50 % flowering and were significantly different ($P<0.05$) from seven (7) varieties (35127-1-1, 35127-1-2, 36461-2, IS 23541, IS 23555, IS 23566-1 and IS 23566-2) that had values above the average days to 50 % flowering. The differences in the days to 50 % flowering could be attributed to genotypic differences among the sweet sorghum varieties.

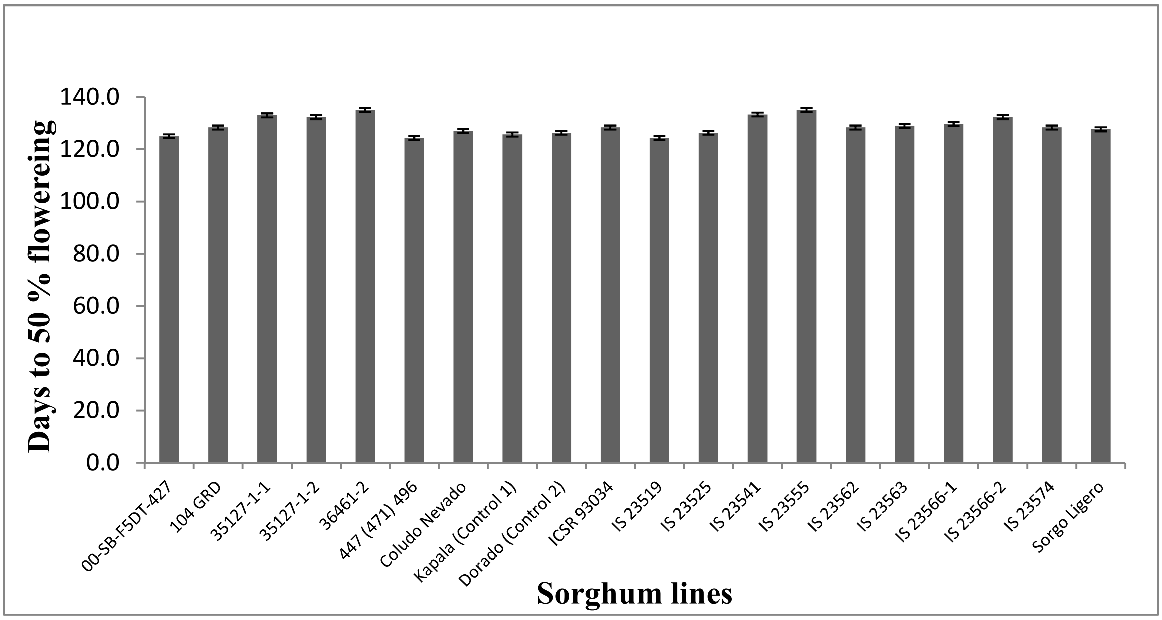

Figure 1. *Average number of days to 50 % flowering of sorghum varieties. (The error bars represent standard error).*

4.2. Striped Stalk Yield (SSYLD) of Sorghum Lines at Three Physiological Growth Stages

The stripped stalk yield (SSYLD) of the twenty (20) sweet sorghum varieties were significantly different ($P < 0.05$) at each of the three physiological growth phases; flower, soft and hard dough stages (Table 2). The SSYLD values at the flowering stage ranged between 223 kg/ha -1319 kg/ha with an average SSYLD value of 778 kg/ha. At this stage of physiological growth, the control variety (Dorado) recorded the poorest striped stalk yield (223 kg/ha) whereas the highest SSYLD was observed in IS 23541 (1319 kg/ha). However, during the soft and hard dough stages, the SSYLD values recorded ranged from 213-1166 kg/ha and 235-1830 kg/ha respectively. The two control varieties (Dorado and Kapaala) had the lowest SSYLD values at the soft and dough growth stages while 35127-1-2, and IS 23555 had highest striped stalk yield both at the soft and hard dough stages. Generally, an increasing trend of SSYLD was observed with the physiological growth phase [Figure 2]. The SSYLD of most of the varieties were lower at flower but increased at soft dough stage and highest at the hard dough stage. On average, the control varieties Kapaala and Dorado had poor SSYLD values at all the physiological growth phases whereas the following improved Sweet Sorghum varieties 35127-1-2, 36461-2, IS 23525, IS 23555, IS 23566-1, IS 23566-2, and IS 23574 showed outstanding performance in terms of striped stalk yield. The significant variations in the SSYLD values observed is an indication that genotypic differences among the sweet sorghum lines influenced the striped stalk yield in this study as reported in similar study by Sanjeevreddi (2006).

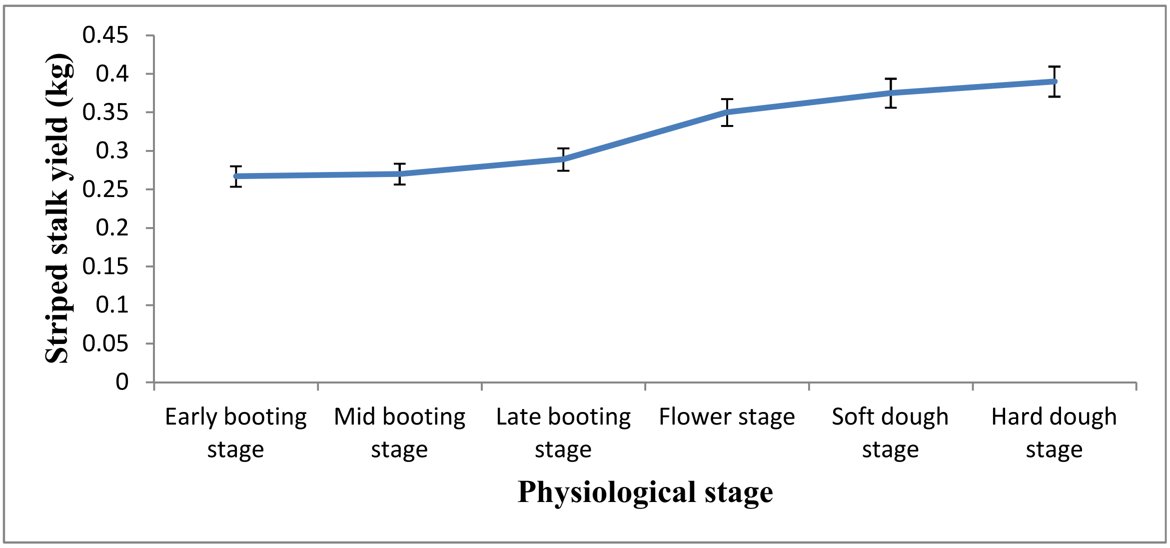

Figure 2. *Average striped stalk yield at the various physiological stages. The error bars represent standard error.*

Table 2. *Striped stalk yield at flowering, soft dough and hard dough stages of plant growth.*

Entry No.	Entry Name	Striped Stalk Yield (SSYLD) in Kg/ha		
		Physiological growth stages		
		Flower (FL)	Soft dough (SD)	Hard dough (HD)
1	00-SB-F5DT-427	512^{abc}	712^{bc}	772^{cd}
2	104 GRD	483^{ac}	559^{bd}	837^{cd}
3	35127-1-1	895^{b}	931^{ab}	1038^{bc}
4	35127-1-2	978^{bd}	1161^{a}	1667^{ab}
5	36461-2	936^{bd}	1166^{a}	1183^{abc}
6	447 (471) 496	537^{abc}	635^{bc}	396^{d}
7	Coludo Nevado	951^{bd}	1030^{ac}	681^{cd}
8	Kapaala (control 1)	622^{abc}	334^{bd}	418^{cd}
9	Dorado (control 2)	223^{c}	213^{d}	235^{d}
10	ICSR 93034	621^{abc}	1010^{ac}	1013^{bc}
11	IS 23519	845^{b}	781^{ac}	837^{c}
12	IS 23525	809^{ab}	1027^{ac}	1204^{b}
13	IS 23541	1319^{d}	588^{bd}	807^{c}
14	IS 23555	937^{bd}	1091^{a}	1830^{a}
15	IS 23562	663^{ab}	965^{ac}	706^{c}
16	IS 23563	595^{abc}	758^{bc}	890^{c}
17	IS 23566-1	911^{ab}	1092^{a}	1324^{ab}
18	IS 23566-2	951^{bd}	983^{ac}	1059^{bc}
19	IS 23574	497^{ac}	993^{ac}	1129^{bc}
20	Sorgo Ligero	553^{abc}	713^{bc}	969^{c}
Mean		778	830	867
LSD		399.8	402.3	517.6
P-value		0.001	0.001	0.001

Means within the same column with no superscript in common are significantly different ($P < 0.05$). LSD = Least significant difference.

4.3. Panicle Weight at Physiological Maturity

The panicle weight (kg /ha) was not significantly ($p > 0.05$) influenced by the genotype of the sweet sorghum lines as shown in [Figure 3]. The panicle weights measured ranged from 124 kg/ha – 773 kg/ha with an average panicle weight of 407 kg/ha. Twelve (12) of the varieties (00-SB-F5DT-427, 35127-1-2, 36461-2, Coludo Nevado, Kapaala, Dorado, IS 23519, IS 23541, IS 23555, IS 23562, IS 23566-1, and IS 23566-2 had measured below the average panicle weight whereas eight (8) of the improved sweet sorghum varieties including 104 GRD, 35127-1-1, 447(471)496, ICSR 93034, IS 23525, IS 23563, IS 23574, and Sorgo Ligero were above the average scores. Even though, the variation in the panicle weight among the twenty variety was insignificant ($p > 0.05$), the following varieties 104 GRD, ICSR 93034, IS 23563, and IS 23574 were outstanding in terms of panicle weight whereas Coludo Nevado, and Kapaala varieties had the poorest panicle weight as compared to the other improved sorghum varieties.

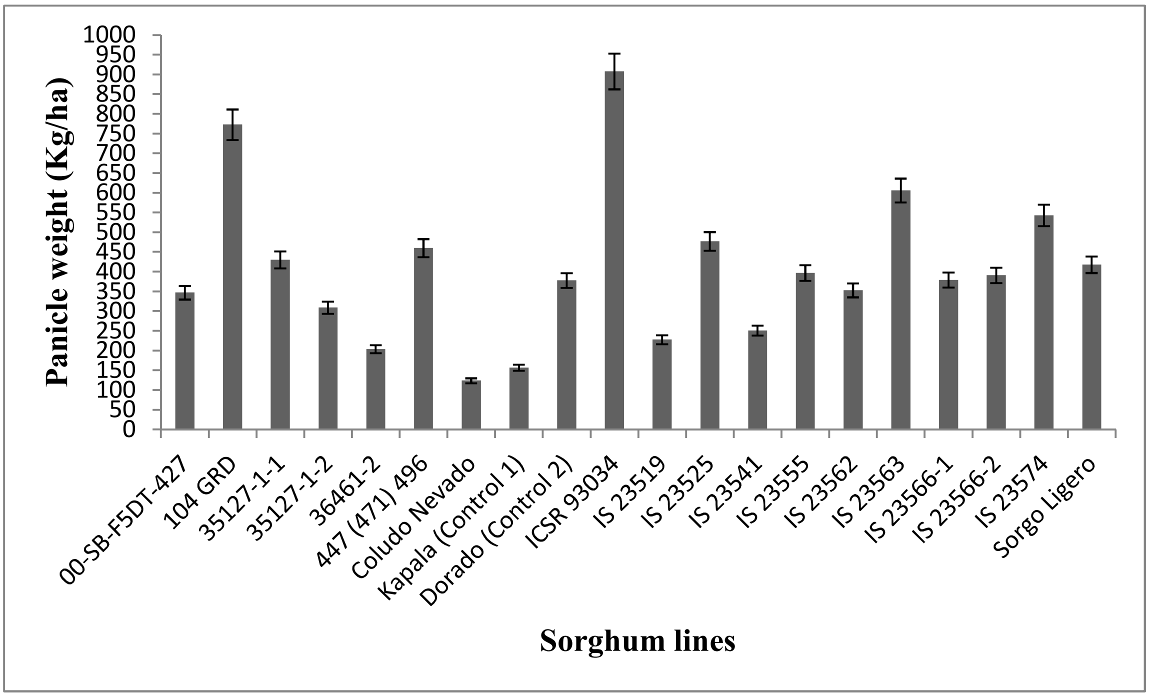

Figure 3. *Average panicle weight (kg/ha) of twenty (20) sweet sorghum varieties. The error bars represent standard error.*

4.4. Grain Weight

There were no significant variations ($p > 0.05$) in the grain yields among the twenty sorghum varieties. The grain yield recorded for the twenty sorghum varieties ranged between Coudo Nevado (50 kg/ha) to 632 kg/ha (ICSR 93034) and an average grain yield of 241 kg/ha. Four varieties namely ICSR 93034, 104 GRD, IS 23562, and IS 23574 had the highest grain yield [Figure 4]. The non-significant differences in the grain yields suggest that differences in the genotype of sweet sorghum lines did not influence this trait. Similar observation was reported by Sanjeevreddi (2006).

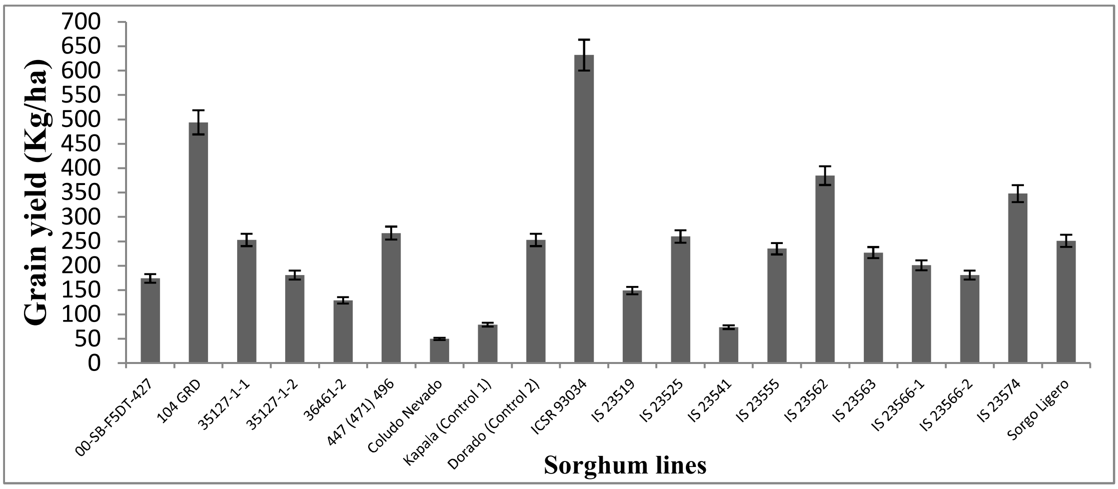

Figure 4. *Average grain yield (Kg/ha) of the sweet sorghum varieties. The error bars represent standard errors.*

4.5. Sugar Content (Brix %) of Stalk Juice of Twenty (20) Sweet Sorghum Varieties at Six Different Physiological Growth Phases

Generally, the sugar content (brix %) of juice extracted from stalks of the twenty sweet sorghum lines increased with increasing growth. The sugar content (brix %) in the stalk juice was lower at the early, mid and late booting stages of physiological growth but increased steadily at the flowering stage and highest during the hard dough stage [Figure 5]. The sugar content (brix %) of the stalk juice from flower to hard dough stage ranged between 6.2 – 21.4 % (Table 3). It varied significantly ($p < 0.05$) among the varieties at almost all the stages of growth with the exception of the flower stage where significant variation was not observed among the sweet sorghum varieties. Even though, the percentage sugar at hard dough stage did not vary significantly ($p > 0.05$) from those recorded at the soft dough stage, the values recorded were slightly higher at hard dough stage. However, the sugar content of stalk juice at these stages were significantly higher ($p < 0.05$) than those measured at the early booting, mid-booting, late booting and flower stages. The sugar contents (brix %) of stalk juice ranged between (6.2–12.0 %), (6.8 – 12.2 %), (7.7 – 13.3 %), (11.1–17.3 %), (12.5 – 19.6 %), and (11.9 – 21.4 %) for early, mid and late booting, flower, soft dough and hard dough stages respectively. The sugar content (brix %) of stalk juice at early, mid and late booting (6.2–12.0 %), (6.8 – 12.2 %), and (7.7 – 13.3 %) respectively were lower than the sugar values (2-20 %) of sweet sorghum cultivars reported earlier by Undersander et al. (1990) but were within the range of sugar values (5.8 – 13.7 %) recorded by Putnam et al. (1991). However, brix percentage of all the sweet sorghum varieties at flowering (11.1- 17.3 %), soft dough (12.5 – 19.6 %), and hard dough (11.9 – 21.4 %) stages of growth were similar to those reported by Undersander et al. (1990).

This is an indication that sugar accumulates as the sorghum plant grows and the highest sugar content of the juice can be obtained at the hard dough stage when the grains of the sorghum plant are physiologically matured and can be harvested. This confirms the earlier findings that Sweet sorghum starts accumulating sugars immediately after anthesis until physiological maturity (Fortmeier and Schubert, 1995). This suggests that the sweet sorghum plant has dual-purpose since both grains and sugar can be produced from the same plant for food and ethanol production respectively, unlike the other cereals such as maize.

Generally, the control varieties (Kapaala and Dorado) recorded the lowest stalk sugar values throughout the six stages of growth. The following improved sweet sorghum lines 35127-1-1, 36461-2, IS 23525, IS 23541, IS 23541, IS 23555, IS 23566-1, IS 23566-2, and IS 23574 had the highest sugar content in their stalk juice at the hard dough stage as shown in Table 3. The variation in the sugar percentage of the stalk juice among the sweet sorghum varieties could be attributed to the genotypic differences. The highest amount of sugar content observed at the hard dough stage suggests that these improved sweet sorghum lines could be used for both grain and sugar production.

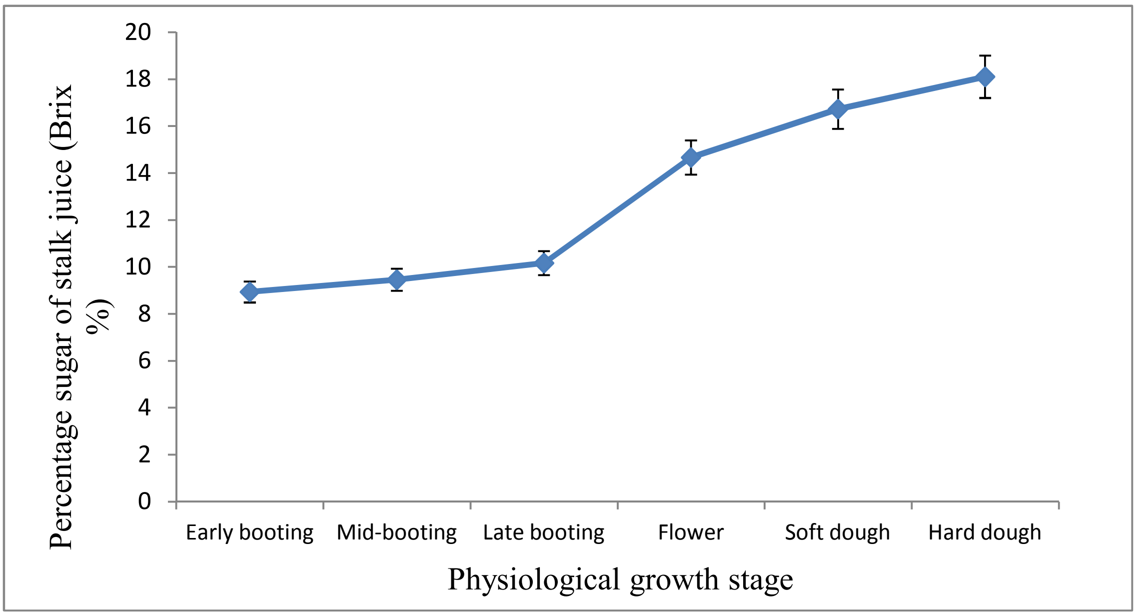

Figure 5. *Average sugar content (brix %) of stalk juice of sweet sorghum at six physiological growth stages. The error bars represent standard error.*

Table 3. *Percentage sugar (Brix) in stalk juices of sweet sorghum varieties at different physiological stages of growth.*

Entry No.	Entry Name	Percentage (%) Sugar (Brix) in stalk juice					
		Physiological growth stages					
		EB	MB	LB	FL	SD	HD
1	00-SB-F5DT-427	8.1	9.9	11.0	15.1	16.3	17.7
2	104 GRD	9.2	9.0	8.9	14.9	15.0	15.8
3	35127-1-1	10.5	12.4	12.6	17.3	19.1	20.7
4	35127-1-2	7.3	7.7	9.5	13.9	15.5	17.1
5	36461-2	9.3	9.7	11.0	15.2	17.3	19.1
6	447 (471) 496	9.2	11.1	10.0	16.5	17.9	17.5
7	Coludo Nevado	6.6	7.7	8.1	13.7	17.1	17.5

Entry No.	Entry Name	Percentage (%) Sugar (Brix) in stalk juice					
		Physiological growth stages					
		EB	MB	LB	FL	SD	HD
8	Kapaala (control 1)	6.2	6.8	7.7	11.1	12.7	11.9
9	Dorado (control 2)	8.9	8.4	8.1	13.3	12.5	14.8
10	ICSR 93034	9.2	8.3	9.6	14.4	16.5	17.8
11	IS 23519	8.1	8.1	8.9	14.3	14.6	17.7
12	IS 23525	9.3	10.0	10.1	15.1	16.5	18.3
13	IS 23541	12.0	10.9	13.1	15.5	19.6	21.4
14	IS 23555	10.9	12.2	12.7	16.1	17.7	19.9
15	IS 23562	8.7	8.3	9.1	13.7	19.3	19.9
16	IS 23563	7.3	8.7	9.4	15.3	17.1	20.0
17	IS 23566-1	10.6	10.7	11.9	15.1	18.1	19.9
18	IS 23566-2	10.3	10.3	13.3	16.3	19.4	20.5
19	IS 23574	10.1	11.0	9.8	15.1	17.0	18.5
20	Sorgo Ligero	7.0	7.9	8.7	13.3	15.6	16.1
Mean		8.9	9.5	10.2	14.8	16.7	18.1
LSD		0.040	0.004	0.001	0.130	0.001	0.001
P-value		0.04	0.004	0.001	0.130	0.001	0.001

The physiological growth stages: EB = early booting, MD = mid-booting, LB=late booting, FL= flowering, SD= soft dough, HD= hard dough stages.

5. Matrix Correlation between Measured Parameters

All traits of sweet sorghum varieties measured were correlated as shown in Table 4. The striped stalk yield (SSYLD) and brix percentage of stalk juice measured at the six physiological growth stages were positively correlated to the number of days to 50 % flower. This confirmed the findings of Amukelani and Wolfgang (2010) in a related study that flowering dates correlated significantly with all traits. However, with the exception of brix percentage at flower stage, there exist negative correlation between grain weight and all the other traits measured ($p < 0.05$). The higher positive correlation among the brix contents of stalk juice at flower, soft dough and hard dough stages, further explains the earlier statement that sugar accumulates as the sorghum plant grows. This was clear in Table 3 that almost all sorghum varieties that had higher sugar content at the initial stages of growth, recorded the highest sugar percentages in the stalk juice during the later phase of growth. The negative correlation between grain weight and sugar content of stalk juice at soft and hard dough stage may be attributed to the fact that sugar accumulated in stalk of sweet sorghum at flower stage is later transported to the grain until certain stage of growth (physiological maturity) when the sugar is permanently stored in the stalk (Fortmeier and Schubert, 1995). Therefore high amounts of sugar in the grain could lower the amount stored in the stalk juice at soft dough and hard dough phases of physiological growth since there may be less sugar accumulation in the stalk.

Table 4. *Matrix Correlation between brix %, growth and yield parameters of the sorghum lines.*

Parameters	Brix % (FL)	Brix % (SD)	Brix % (HD)	DFL	SSYLD (FL)	SSYLD (SD)	SSYLD (HD)	GWT
Brix % (FL)								
Brix % (SD)	0.4935***							
Brix % (HD)	0.6193***	0.7793***						
DFL	0.1462	0.3127*	0.2694*					
SSYLD (FL)	0.3412**	0.4362**	0.4528***	0.3461**				
SSYLD (SD)	0.2987*	0.3923**	0.4521***	0.2389	0.4678***			
SSYLD (HD)	0.1637	0.2314	0.3197**	0.3585**	0.2898*	0.4851***		
GWT	0.0169	-0.1125	-0.0956	-0.1123	-0.2046	-0.0344	-0.0704	

In the table above *represents significant at the 0.05 probability leve1, ** significant at the 0.01 probability leve1 and*** significant at the 0.001 probability level. GWT = Grain weight; DFL = Days to 50 % percent flowering; SSYLD = striped stalk yield (kg/ha); FL = flowering stage; SD and HD represent soft dough and hard dough stages respectively:

6. Conclusion and Recommendation

The study conducted revealed that the sweet sorghum varieties 35127-1-1, 36461-2, IS 23525, IS 23541, IS 23555, IS 23562, IS 23563, IS 23566-1, IS 23566-2 and IS 23574 had best performances throughout the physiological stages in terms of stalk yield and brix percentage of stalk juice and can be recommended for ethanol production. On the other hand the following two improved sweet sorghum varieties 104 GRD, ICSR 93043 had the highest grain and panicle weights. However, for dual-purpose (grain and sugar), the sorghum lines IS 23562 and IS 23574 showed outstanding performances. Generally, Kapaala and Dorado varieties had the poorest sugar yield whereas Coludo Nevado, Kapaala and IS 23541 recorded the lowest grain yield. It is recommended that more multi-locational trials should be conducted to evaluate the performance of these improved sweet sorghum varieties before recommending the best to farmers. Otherwise, the high grain yielding but low sugar yielding sorghum varieties should be crossed with the low grain yielding but high sugar yielding cultivars to breed for both high grain and sugar yielding sorghum varieties that can serve dual purpose to help combat the hunger and energy crisis in developing countries and the world as a whole.

References

[1] Amukelani S. and Wolfgang F., Genotype-environmental analysis of RIL population segregating for sugar-related traits in Sorghum bicolour L. Moench. A dissertation submitted for the degree of Doctor of Agricultural Science, Faculty of Agricultural Sciences, Nutritional Sciences and Environmental Management Justus-Liebig-University Giessen, 2010.

[2] Arneja C.S., Maurya V.N. and Kaur Gaganpreet, Entrepreneurship development of Punjab farmers based on statistical survey, Journal of Engineering and Technology Research, Scientia Research Library, Georgia, Vol. 2(1), pp. 1-9, 2014, ISSN: 2348-0424, USA CODEN JETRB4

[3] Fortmeier R. and Schubert S., Storage of non-structural carbohydrates in sweet sorghum [Sorghum bicolour (L.) Moench.]: Comparison of sterile and fertile lines. J. Agronomy and Crop Science, Vol. 175, pp189-193, 1995.

[4] Ganjyal G., Fang Q., and Hanna M.A., Freezing points and small scale de-icing test for salts of levulinic acid made from grain sorghum. Bio-resource Technology, Vol. 98, pp.2814–2818, 2007

[5] Maurya V.N., Arora Diwinder Kaur, Maurya A.K. and Gautam R.A., Numerical simulation and design parameters in solar photovoltaic water pumping systems, American Journal of Engineering Technology, Academic & Scientific Publishing, New York, USA, Vol.1(1), pp. 1-09, 2013

[6] Maurya V.N., Arora Diwinder Kaur, Maurya A.K. and Gautam R.A., Exact modelling of annual maximum rainfall with Gumbel and Frechet distributions using parameter estimation techniques, World of Sciences Journal, Engineers Press Publishing, Vienna, Austria, Vol.1(2), pp.11-26, 2013, ISSN: 2307-3071

[7] Maurya V.N., Maurya A.K. and Kaur D., A survey report on nonparametric hypothesis testing including Kruskal-Wallis ANOVA and Kolmogorov–Smirnov goodness-fit-test, International Journal of Information Technology & Operations Management, Academic and Scientific Publishing, New York, USA, Vol.1(2), pp. 29-40, 2013, ISSN: 2328-8531

[8] Maurya V.N., Singh Bijay, Reddy N., Singh V.V., Maurya A.K., Arora D.K., Cost-effective perspective and scenario development on economic optimization for multiple-use dry-season water resource management, American Open Journal of Agricultural Research, Academic & Scientific Publishing, New York, USA, Vol. 2(1), pp. 1-21, 2014, ISSN:2333-2131

[9] Putnam D.H., Lueschen W E., Kanne B.K. and Hoverstad T.R., A comparison of sweet sorghum cultivars and maize for ethanol production. Journal of Production Agriculture, Vol.4 (3), pp 377-381, 1991

[10] Sanjeevreddi G.R., Studies on production potential of sweet sorghum [sorghum bicolor (l.) moench] genotypes for grain and ethanol production as influenced by management practices, PhD Thesis, University of Agricultural Sciences, Dharwad, 2006.

[11] Savannah Agricultural Research Institute (SARI), Agro-metrological unit. Annual Report, pp.22, 2004

[12] Schaffert R.E., Sweet sorghum substrate for industrial alcohol: Utilization of sorghum and millets, Proceedings of the International workshop on policy, practice, and potential relating to uses of sorghum and millets, pp. 131-137, 8-12 Feb. 1988, ICRISAT Centre, Bulawayo, Zimbabwe. International Crops Research Institute for the Semi-Arid Tropics, 1992.

[13] Seetharam A., Biofuel in Africa: A criteria to choose crop models for food and fuel, ATDF Journal Vol.4, pp.3-12, 2005

[14] Shoemaker C.E. and Bransby D.I., The role of sorghum as a bioenergy feedstock, Department of Agronomy and Soils, 202 Fun chess Hall, Auburn University, Auburn, U.S.A., 2010

[15] Tarpley L. and Vietor D.M., Compartmentation of sucrose during radial transfer in mature sorghum culm. BMC Plant Biology, Vol. 7,pp .33, 2010.

[16] Undersander D.J., Lueschen W.E., Smith L.H., Kaminski A.R., Doll J.D., Kelling K.A. and Oplinger, E.S., Sorghum for Syrup, 1990. Also available at http://www.hort.purdue.edu/newcrop/afcm/syrup.html.