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Adaptation of Released Sorghum Varieties Evaluation in Tendahoo Sugar Factory, Afar Regional State of Ethiopia

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Abstract

Six Sorghum genotypes were evaluated in RCBD with three replications at Tendaho Sugar Factory for two years in surface irrigation for two years. Genotypes included in the test in 2017 differed significantly at (p 0.05) probability level with respect to Days of Heading/days of flowering(DH), Plant height (PHM), stand count at harvest (SCH) and thousand seed weight (TSW) characters. The analysis of variance for 2018 data result indicated that the existence of significant variability (p 0.05) for all studied characters Days of Emergency, Days of Maturity, No of Tillers, No of Effective Tillers, Plant Height maturity, Panicle length (cm), No of spikelet/spike, Grain Yield kg/plot, Grain Yield Qt/Ha and Biomass kg/ha except Days of heading and thousand kernel weight which result non significant variation.

Keywords: Genotype, variability, Tendaho

Introduction

Like most developing countries, Ethiopia relies much on agriculture to drive economic growth. Despite considerable and dynamic efforts made towards increasing agricultural production, the country has yet to go a long way to secure self-sufficiency in strategic food crops. Consequently, the country is obliged to import large quantities of wheat and other grains even in normal year. The grain deficit worsens in drought years such as in 2015(Adaptation and Promotion project document 2016). During this year, the country imported an account of 3.2 million metric tons of wheat to close the deficit. On the contrary, a number of reports have shown that Ethiopia has good agricultural potential that would allow it to produce surplus quantities of agricultural commodities let alone meeting its food security strategy dependant merely on rain-fed agriculture through harnessing its fertile and irrigable land in the lowland areas. However, to date much of the irrigable low lands are not yet utilized for various reasons (Adaptation and Promotion project document, 2016).

Sugarcane is rapidly becoming one of the most important industrial crops in the world, Owing its suitability to the low land areas and associated benefit of sugar production, the GoE has targeted to place Ethiopia among the top 10 sugar producing nations in the world by 2023 (ESC). Among newly established sugar estates Kuraz, Beles and Tendaho have bigger farm land size that ranges between 50 and 175 thousands of hectares (ESC). To date, the newly established sugar factories have not reached at a stage of utilized all their allocated land resource as initially planned (Adaptation and Promotion project document, 2016).

Therefore, there is an opportunity to make use of the under-utilized land for other agricultural production until the factories become fully operational. Global experiences showed that most sugar producing countries such as India, Thailand, Australia, South Africa and Brazil are running their sugar industries with complementary crops and livestock's enterprises. In India, vegetable and pulse crops are produced as rotational and diversification crops at sugar cane farms. Similarly in South Africa, sugar estates are also linked with beef production. In this regard, the Ethiopian Sugar Corporation (ESC) has established a wing tasked with crop, horticulture and livestock production to enhance product diversification.

However, most of the intended large fertile low land areas have not been covered by national agricultural research system in developing improved crop varieties yet. Thus, it seems crucial to undertake a quick adaptation trial at each location so as to venture on large scale mechanized cereal and forage crop production in selected sugar estates. To achieve this, there is a need to undertake adaptation trial of Sorghum in the sugar estates in order to identify suitable variety for Tendaho Sugar Estate.

Sorghum has its origin in Ethiopia and from here it spread to other parts of Africa, India, Asia, Australia and the US. (Tawanda, 2004; ICRISAT, 2005). Ethiopia is one of the centers of origin and domestication of sorghum and has an immense genetic diversity in the country diversified forms of the crop and its wild relatives represent possible sources of germplasm for crop improvement. Source of Novel genes and High lysine sorghum (Singh & Axtel, 1973) are characteristics of Ethiopian Sorghum.

Sorghum is indigenous to Ethiopia contributes about 20-22% of total cereal production which is very important crop in the lowland arid and semi-arid areas which is dominant crop in areas where soil fertility degradation and drought stress are key constraints. Sorghum grows in 12 of the 18 major agro-ecological zones and stands 3rd next to teff and maize in area coverage while in moisture stress lowland areas of the country, it is the first both in area and production and second in total production next to maize (Feed Africa, 2015). It covers 16% of the total area allocated to grains and 20% of the area covered by cereals (CSA, 2013). Currently Sorghum covers 1.83 million ha area and 4.34 million quintals production with national average grain productivity 24 q/ha 5.7 million smallholder farmers grow sorghum (CSA, 2013). It is cultivated in all regional states of Ethiopia in altitude ranges of 400m to 2500m potential to produce a yield of 30-60Qt/ha using improved varieties and production practices (CSA, 2013). One of the major traditional food crops of Ethiopia and the second most important crop for Injera making quality next to teff.

Therefore, the objective of this experiment was to evaluate the adaptation performance of the tested sorghum genotypes to identify the high yielding and heat tolerant sorghum varieties that are highly adapted to Tendaho sugar plantation estate in order to enhance the net national crop production in general and product diversification in sugar estates in particular in the near future.

Materials and Methods

Description of the study area

Tendaho Sugarcane Estate is found in Afar Regional State North Eastern part of Ethiopia, that is located at 41°3’E longitude and 11°50’ N latitude, receiving annual rainfall of about 200 mm with mean minimum and maximum temperature of 22.91°C and 37.72°C, respectively. The altitude of the specific area is 374 m above sea level.

Temperature

Table 1. 53 years Average Temperature from 1953 to 2016 of Tendaho

	Months												
	JAN	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Average
Temperature in ^{0}c	23	24.4	26	28.1	30.8	31.9	31.5	30.5	30.7	27.2	24.7	23.3	27.7

Materials

The following six candidate Sorghum genotypes were used for the Sorghum Variety Adaptation Trial which are:- Melkam, Dekeba, Teshale, ESH 1, ESH 3 and ESH-4.

Methods

Six candidate genotypes were tested in RCBD with three replications following appropriate statistical procedures. This activity targets to evaluate adaptation ability and yield potential of the candidate varieties and identify the best performing genotype under Tendaho conditions. The plot size for the trial was 10 m by 10 m. The trial was carried out using surface irrigation in Ten days interval for 12 times frequency from November 2016 to April 2017 (Year one) and November 2017 to April 2018 (year Two) following recommended agronomic practices. Crop performance data on days to flower, days to maturity, plant height, disease incidence, insect attack, Stand count at harvest, 100 seed weight and grain yield were recorded.

The following data were collected from the trial:-

Number of total tillers per plot (TT): The total tiller populations were recorded from five randomly taken samples using $1m^2$ quadrants in each plot and converted to plot basis at before time of heading.

Number of effective tillers per plot (ET): The total Effective tiller populations were recorded from five randomly taken samples using $1m^2$ quadrants in each plot and converted to plot basis after heading of the plants.

Plant height (PLH): plant Height in centimeter was measured from ground level to the top of the spike excluding the awn of twenty randomly taken plants from all rows of the plot and recorded as the average height per plant.

Panicle length (PL): The main spikes from twenty sampled plants of each plot were measured in cm and averaged to represent the spike length in cm.

Number of spikelet's per panicle (SLSP): The number of spikelets in main tillers of each of the twenty randomly taken plants was taken and averaged to represent the number of spikelts per plant.

Number of normal kernels per panicle (NKSP): The number of normal seeds in each panicle was recorded from 20 plants randomly selected plants in each plot and averaged to represent number of normal (fully filled grain) seeds per single panicle.

Number of Aborted kernels per panicle (ABKSP): The number of Aborted seeds (seeds did not filled its grain) in each panicle was recorded from 20 plants randomly selected plants in each plot and averaged to represent number of aborted seeds per single panicle.

Date of emergence (DE): Number of days from sowing up to the date of 50% germination of the plant in a plot was recorded in plot basis.

Date of heading (DH): The number of days from sowing up to a date when 50% of the plants in a plot had produced spikes was recorded in plot basis.

Date of maturity (DAM): The number of days from sowing to physiological maturity where 8% of the plants became mature in each plot and when 85% of the crop stands; stems, leaves and floral bracts changed to light yellow color was recorded in plot basis.

Thousand-kernel weight (TKW): Grain weight of thousand seeds sampled at random from total grain harvest of the experimental plot was recorded by analytical balance expressed in gm.

Above ground biomass (ABGM): the total above ground biomass in kilo gram of all the plants was recorded by collecting and weighing the samples randomly taken from five places of each plot using $1m^2$ quadrants at harvest and finally converted to and expressed in plot basis.

Grain Yield (GY) per hectare: The grain yield in kilo gram at 14 % seed moisture content obtained by harvesting the whole plants from each plot was measured per plot basis and converted to quintals per hectare basis.

Analysis of variance:

The data obtained for different traits was statistically analyzed using GenStat 15th Edition Software. Analysis of Variance for RCBD design was computed for the characters such as Date of planting, Stand count at emergency, Stand count at harvest, Date of heading, Date of flowering, Date of maturity, Plant height in cm at maturity, harvest index and thousand seed weight. Separate and combined analysis were done for each year data and presented here.

Mean comparisons among treatment means were conducted by Least Significance Difference (LSD) methods at 5% levels of significance.

The RCBD design analysis of variance was used to derive variance components as structured as stated by Cochran and Cox, (1957).

RCBD ANOVA was computed using the following model: $Yij = \mu + rj + gi + \varepsilon ij$

Where, Yij = the response of trait Y in the ith genotype and the jth replication

μ = the grand mean of trait Y   gi = the effect of the ith genotype
rj = the effect of the jth replication   εij = experimental error effect

Data Analysis for Profitability Analysis

I. Sources of Data for profitability analysis

In this study primary and secondary sources of data were used. Wheat genotypes farm production data of the adaptation experiment result was also used as a primary source of data.

II. Data Analysis for profitability analysis

In this study descriptive statistics was implemented as a tool for data analysis. Gross income and net income of the farm was used to compare the profitability of alternative wheat genotypes.

Johnson (1982) and Kay (1986) recommended the use of net farm income (NFI) in ascertaining the profitability of farmers. NFI, according to them is derived after obtaining the gross margin (GM) of a farm. GM is the amount of money realized after deducting variable expenses or costs from total sales or income. NFI is obtained by adjusting net cash farm income for total depreciation, net inventory changes and value of products consumed at home. NFI, according to Kay (1986) is the only true measure of profit for the accounting period since it includes the above adjustment which could be quite large. NFI is the profit from the year's operation and represents the return to the farm owner for personal and family labor, management and equity capital used in the farm business.

Total Income (Gross Income) analysis

$$R_i = Q_i P_i \quad \text{---------------} (1)$$

Where:
- Ri = Total average income per hectare of individual crops
- Qi= Annual average yield (Qt/ha) of individual crops
- Pi= Average selling price (ETB/Qt) of individual crops

$$GM = TI - TVC \quad \text{---------} 2)$$

Where:
- GM = Gross Margin
- TI = Total income
- TVC = Total variable cost

Net Farm Income Analysis

$$NFI = GM - TFC \quad \text{-------------} (3)$$

OR

$$NFI = TI - TC$$

Where:

- TC = Total Cost
- NFI (Net Profit) = Net Farm Income
- TFC = Total Fixed Cost

Results and Discussion

Variance analysis

The combined years analysis of variance shown that genotypes included in the test differed significantly at (p 0.05) for Days of Heading, Days of Maturity, No of Tillers, No of Effective Tillers, Plant Height at maturity, Panicle length (cm), No of spikelet/spike, Thousand kernel weight, and Biomass kg/ha. While, non significant variability were recorded for Days of Emergency and Grain yield (Table 2).

The result indicated that there was significant amount of phenotypic variability and all the genotypes differ each other with regard to the studied characters except grain yield and days of emergency that opened a way to proceed for further improvement through simple selection.

Table 2. Combined Year Analysis of Variance for six Sorghum Genotypes adaptation evaluation in Tendaho (2017 and 2018)

Characters	s.s.	m.s.	v.r.	F pr.
Grain yield (Qt/Ha)	577.5	115.5	2.1	0.1
Error	1595.1	55		
Biomass (kg/ha)	39807	7961	4.7	0
Error	49035	1691		
Days of Emergency	21.7	4.3	2.2	0.1
Error	58.3	2		
Days of Heading	235.9	47.2	5.3	0
Error	259	8.9		
Days of Maturity	350.6	70.1	5.1	0
Error	395.2	13.6		
Grain yield (kg/plot)	567.7	113.5	2.1	0.1
Error	1576.9	54.4		
Number of Effective tiller per ha	320134	64027	4.8	0
Error	385853	13305		
Total Tiller per hectare	834546	166909	3.9	0
Error	1257783	43372		
Plant Height (cm)	82380.1	16476	258.4	<.001
Error	1849	63.8		
Panicle length (cm)	418.3	83.7	5.8	<.001
Error	417.3	14.4		
Spikelet/spike	684.8	137	4.5	0
Error	893.1	30.8		
Thousand kernel weight (gm/1000 seed)	197.1	39.4	1.9	0.1
Error	591.8	20.4		

The analysis of variance for 2017 data shown that genotypes included in the test differed significantly at (p 0.05) probability level with respect to Days of Heading/days of flowering(DH), Plant height (PHM), stand count at harvest (SCH) and thousand seed weight (TSW) characters (Table 3). The result indicates that there was significant amount of phenotypic variability and all the genotypes differ each other with regard to the studied characters except grain yield and days of maturity that opened a way to proceed for further improvement through simple selection.

Whereas, the analysis of variance for 2018 data result indicated that the existence of significant variability (p 0.05) for all studied characters Days of Emergency, Days of Maturity, No of Tillers, No of Effective Tillers, Plant Height maturity, Panicle length (cm), No of spikelet/spike, Grain Yield kg/plot, Grain Yield Qt/Ha and Biomass kg/ha except Days of heading and thousand kernel weight which result non significant variation. The result revealed the existence of genetic variation among tested genotypes so as based on the obtained result simple selection could be possible to recommend superior variety that adapt Tendaho (Table 4)

Similarly, Geleta and Labuschagne (2005) found the existence of morphological variation among sorghum accessions collected from eastern parts of Ethiopia using 10 morphological traits. Teshome et al. (1997) evaluated 117 sorghum accessions from the North Shewa and South Welo regions of Ethiopia based on 14 morphological traits and reported extensive variation of the accessions. Grenier et al. (2004) observed the morphological diversity among sorghum accessions as well as a high level of diversity within each region and was distributed with geographical origin using 2 017 Sudanese sorghum landraces. Barro-Kondombo et al. (2010) also found a high level of morphological and genetic variability in sorghum varieties from Burkina Faso.

Table 3. ANOVA (2017) of Six Sorghum genotypes for seven studied characters at Tendaho Sugar Estate 2017

Traits	Days of Heading	Days of Maturity	Grain yield Qt/Ha	Grain Yield kg/plot	Plant Height at Maturity	stand count at maturity	thousand kernel weight
MS	43.56*	3.16	101.26	101.26	9273.94*	42681*	26.81*
EMS	6.922	2.389	36.79	36.79	92.37	4533	9.816

Where: * indicates significant at 0.05, Treatment Mean Square = t MS, Error Mean Square= EMS,

Table 4. Analysis of variance of six Sorghum genotypes for twelve studied traits in Tendaho 2018

Traits	DE	DH	DM	NT	NET.	PHcm	PLcm	Sp/Sp	TKW_gm	GYkgP	GYqtHa	BM
EMS	0.89	10.84	4.762	19485	5462	21.47	0.59	10.26	43.32	12.57	12.96	1421
tMS	5.32	17.98	122.86	117102	55045	8607.29	91.01	105.42	32.06	128.52	132.47	18233
F pr.	0.004	NS	<.001	0.004	<.001	<.001	<.001	<.001	NS	<.001	<.001	<.001

Where: s.s = sum of squire, m.s = mean squire F.pr = calculated probability, DE = Days of Emergency, DH= Days of Heading, DM=Days of Maturity, NT=No of Tillers, NET=No of Effective Tillers, PH(cm)=Plant Height maturity, PLcm=Panicle length (cm), Sp/Sp=No of spikelet/spike, TKW_gm =Thousand kernel weight, GYkgP=Grain Yield kg/plot, GYqtHa=Grain Yield Qt/Ha and BM =Biomass kg/ha

Table 5 Combined Year Mean, LSD and CV Values of Six Sorghum Genotypes Adaptation trial at Tendaho (2017 and 2018)

	GY(Qt/Ha)	BM	DE	DH	DM	GY(kg/p)	NET	NT	PHcm	PanL	Spikelet	TKW
ESH-3	54.2	245.1	6.5	66.0	88.0	53.8	857.0	1390.0	174.0	31.7	53.7	26.4
ESH-1	51.4	314.0	7.3	64.3	88.5	51.0	819.0	1534.0	175.7	29.5	57.4	29.6
Dakaba	50.5	279.6	7.7	71.8	96.8	50.2	791.0	1317.0	134.6	28.0	61.3	26.2
ESH-4	46.8	208.9	7.5	68.5	92.7	46.5	883.0	1514.0	131.1	34.4	63.0	28.0
Melkam	46.2	258.5	8.7	70.5	92.0	45.8	655.0	1190.0	156.4	29.1	54.1	33.1
Teshale	42.0	285.6	6.3	67.2	88.7	41.7	963.0	1652.0	274.2	23.3	50.6	29.8
Gmean	48.5	265.3	7.3	68.1	91.1	48.2	828.0	1432.8	174.3	29.3	56.7	28.8
CV	15.3	15.5	19.3	4.4	4.1	15.3	13.9	14.5	4.6	12.9	9.8	4.0
LSD (5%)	8.8	48.6	1.7	3.5	4.4	8.7	136.2	245.9	9.4	4.5	6.6	5.3

Where: s.s = sum of squire, m.s = mean squire F.pr = calculated probability, DE = Days of Emergency, DH= Days of Heading, DM=Days of Maturity, NT=No of Tillers, NET=No of Effective Tillers, PH(cm)=Plant Height maturity, PLcm=Panicle length (cm), Sp/Sp=No of spikelet/spike, TKW_gm =Thousand kernel weight, GYkgP=Grain Yield kg/plot, GYqtHa=Grain Yield Qt/Ha and BM =Biomass

Morphological traits provide a simple way of measuring genetic diversity while studying genotype performance under normal growing conditions, but are influenced by environmental factors (Tuinstra et al., 1996; Beuningen and Busch, 1997; Abdi et al., 2002; Fufa et al., 2005).

These result points to that the existence of wider variations among the studied genotypes for the studied characters so as simple selection could be possible based on those characters.

Mean Comparison

As indicated in table 5 the mean values of studied varieties for Days of Emergency, Days of heading, Days of Maturity, No of Tillers, No of Effective Tillers, Plant Height maturity, Panicle length (cm), No of spikelet/spike, Grain Yield kg/plot, Grain Yield Qt/Ha thousand kernel weight and Biomass kg/ha indicated significant variability for yield and yield components, hence we can draw conclusion to make selection based on the yield value magnitude.

Yield comparison:

The 2017 data analysis result indicated in table 5 show that the existence of wide variation among genotypes for Grain Yield per hectare (GY (qt/ha)). The mean separation result revealed that the candidate genotype Dakaba (56.3qt/ha) score significantly higher mean value followed by ESH-3 (53.7qt/ha) and the ESH-4 (53qt/ha).

The combined analysis result of the two years (2017-2018) grain yield data as indicated in table 5 shown that ESH-3 recorded highest average productivity followed by ESH-1 and Dakaba with 54.25, 51.45, 50.5 quintal per hectare respectively.

The combined years analysis as Indicated in Table 5, highest grain yield value were recorded for ESH-3 (54.2 Qt/Ha) followed by ESH-1 (51.4 Qt/Ha), Dakaba (50.5Qt/Ha), ESH-4 (46.8Qt/Ha), Melkam(46.2Qt/ha) and Teshale(42.0Qt/Ha). As shown in the table 5 ESH-3(54.2 Qt/Ha), ESH-1 (51.4 Qt/Ha) and Dakaba (50.5Qt/Ha) recorded the first, second and third high grain yield 5.7, 2.9and 2.0 quintals per hectare extra yield respectively over the grand mean (48.5 Quintals per hectare).

Dry Biomass

The combined years analysis as indicated in Table 5, highest dry Biomass value were recorded for ESH-1 (314.0kg/Ha) followed by Teshale (285.6Kg/Ha), Dakaba (279.6kg/Ha), Melkam (258.5kg/Ha), ESH-3 (245.1Kg/Ha), ESH-4 (208.9kg/Ha) and the grand mean 265.6kg/Ha.

Days of 50% Emergency

As indicated from the table 5 for days of 50% Emergency Melkam (8.7), Dakaba (7.7), ESH-4(7.5) and ESH-1(7.3) relatively emerged lately compared to the grand mean for days of 50% emergency while Teshale (6.3) and ESH-3 (6.5) emerged early.

Number of effective tillers per hectare

Highest effective tiller number were recorded for Teshale (963.0), ESH-4 (883.0) and ESH-3(857.0) first, second and third respectively while ESH-1 (819.0), Dakaba (791.0) and Melkam (655.0)

Days of 75% Heading

ESH-1 (64.3), ESH-3 (66.0), Teshale (67.2) and ESH-4(68.5) headed earlier compared to the grand mean while Dakaba (71.8) and Melkam (70.5) flower lately among tested genotypes relatively (table 5).

Days of 75% Maturity

As indicated in the table 5 Dakaba (96.8), ESH-4 (92.7) and Melkam (92.0) relatively matured lately compared to other tested varieties with relative high magnitude over the grand mean (91.1). While ESH-3 (88.0), ESH-1 (88.5) and Teshale (88.7) matured earlier than others.

Spike Length in (cm)

As shown in Table 5 Studied genotypes differed significantly for Spike length in cm with ESH-4 (34.4cm), ESH-3 (31.7cm), ESH-1 (29.5cm), Melkam (29.1cm), Dakaba (28.0cm) and Teshale (23.3cm)

Thousand Kernel weight in gram

As shown in Table 5 Studied genotypes differed significantly for thousand kernel weight in grams were recorded and among the studied genotypes Melkam (33.1gm) scored the first higher value followed by

Teshale (29.8gm) and ESH-1 (29.6gm) while ESH-4 (28.0gm) ESH-3 (26.4gm) and Dakaba (26.2gm)

Economic Advantage of Sorghum Production

The Sorghum grain yield mean value comparative comparison presented in table 5 indicated that the genotype EHE-3, ESH-1 and Dakaba scored the first, second and third highest grain yield productivity average over the two years.

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Profit Analysis of Sorghum Production

The economic analysis result shown that producing Sorghum could provide additional income to the Factory with net profit per Hectare 17,209.3 birr in average. ESH-3 generates 21,742.63 birr highest net income per hectare followed by ESH-1 and Dekeba 19,522.23 and 18,768.88 birr per hectare respectively

Table 6. Profitability of Sorghum genotypes (Qt/ha)

Parameters	Dakaba	EHE-3	Melkam	ESH-1	ESH4	Teshal	Grand Mean
Yield ((ETB/ha)	50.5	54.3	46.2	51.5	46.8	42	48.5
Total Production Cos (ETB/ha)	21,277.62	21,277.62	21,277.62	21,277.62	21,277.62	21,277.62	21,277.62
Selling Price (ETB/Qt)	793	793	793	793	793	793	793
Gross Income (ETB/ha)	40,046.50	43,020.25	36,636.60	40,799.85	37,112.40	33,306.00	38,486.93
Net Income/Net Profit (ETB/ha)	18,768.88	21,742.63	15,358.98	19,522.23	15,834.78	12,028.38	17,209.31

Conclusion and Recommendations

Genotypes included in the test in 2017 differed significantly at (p 0.05) probability level with respect to Days of Heading/days of flowering(DH), Plant height (PHM), stand count at harvest (SCH) and thousand seed weight (TSW) characters. The analysis of variance for 2018 data result indicated that the existence of significant variability (p 0.05) for all studied characters Days of Emergency, Days of Maturity, No of Tillers, No of Effective Tillers, Plant Height maturity, Panicle length (cm), No of spikelet/spike, Grain Yield kg/plot, Grain Yield Qt/Ha and Biomass kg/ha except Days of heading and thousand kernel weight which result non significant variation.

The two years grain yield mean comparison among tested genotypes resulted with ESH-3 recorded the superior grain yield value compared to others followed by ESH-1 and Dakaba with 54.25, 51.45 and 50.5 quintal per hectare respectively.

Therefore, based on the two year 2017 to 2018 adaptation research done at Tendaho Sugar Estate result ESH-3, ESH-1 and Dakaba with greater economic advantage shall be recommended for commercial production at Tendaho and similar agro-ecologies. From this work It is also noted that, the tested genotypes are developed by the national agricultural system for rain fed production so as further research works should have to be done in developing varieties for irrigation, crop irrigation agronomy, determination of fertilizer, planting time and season by considering to the specific Agro-climatic condition of the study area.

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ANNX

Table 1. Combined Year ANOVA, Interaction Effect, R^2 of Six Sorghum Varieties fifteen studied characters

	Source	DF	SeqSS	AdjSS	AdjMS	F	P
DE	Rep	2	4.667	4.667	2.333	1.13	0.34
	Year	1	0	0	0	0	1
	Tret	5	21.667	21.667	4.333	2.1	0.103
	Year*Tret	5	8.333	8.333	1.667	0.81	0.556
	Error	22	45.333	45.333	2.061		
	Total	35	80				
	R-Sq		43.33%				
DH	Rep	2	0.056	0.056	0.028	0	0.996
	Year	1	49	49	49	6.37	0.019
	Tret	5	235.889	235.889	47.178	6.13	0.001
	Year*Tret	5	89.667	89.667	17.933	2.33	0.077
	Error	22	169.278	169.278	7.694		
	Total	35	543.889				
	R-Sq	=	68.88%				
DM	Rep	2	1.556	1.556	0.778	0.27	0.769
	Year	1	1.778	1.778	1.778	0.61	0.444
	Tret	5	350.556	350.556	70.111	23.93	0
	Year*Tret	5	329.222	329.222	65.844	22.48	0
	Error	22	64.444	64.444	2.929		
	Total	35	747.556				
	R-Sq	=	91.38%				
NT	Rep	2	244081	244081	122040	3	0.071
	Year	1	0	0	0	0	1
	Tret	5	834546	834546	166909	4.1	0.009
	Year*Tret	5	117457	117457	23491	0.58	0.717
	Error	22	896245	896245	40738		
	Total	35	2092329				
	R-Sq	=	57.17%				
NET	Rep	2	75356	75356	37678	5.96	0.009
	Year	1	1677888	1677888	1677888	265.24	0
	Tret	5	320134	320134	64027	10.12	0
	Year*Tret	5	171325	171325	34265	5.42	0.002
	Error	22	139172	139172	6326		
	Total	35	2383876				
	R-Sq	=	94.16%				

	Source	DF	SeqSS	AdjSS	AdjMS	F	P
PHcm	Rep	2	61.9	61.9	30.9	0.58	0.566
	Year	1	2141.4	2141.4	2141.4	40.47	0
	Tret	5	82380	82380	16476	311.35	0
	Year*Tret	5	623	623	124.6	2.35	0.074
	Error	22	1164.2	1164.2	52.9		
	Total	35	86370.5				
	R-Sq	=	98.65%				
PaniLcm	Rep	2	9.82	9.82	4.91	0.33	0.724
	Year	1	0	0	0	0	1
	Tret	5	418.26	418.26	83.65	5.59	0.002
	Year*Tret	5	78.53	78.53	15.71	1.05	0.414
	Error	22	328.99	328.99	14.95		
	Total	35	835.6				
	R-Sq	=	60.63%				
SpiletPSp	Rep	2	143.44	143.44	71.72	3.39	0.052
	Year	1	0	0	0	0	1
	Tret	5	684.83	684.83	136.97	6.48	0.001
	Year*Tret	5	284.37	284.37	56.87	2.69	0.048
	Error	22	465.27	465.27	21.15		
	Total	35	1577.92				
	R-Sq	=	70.51%				
GYkgP	Rep	2	340.17	340.17	170.08	5.82	0.009
	Year	1	44.44	44.44	44.44	1.52	0.231
	Tret	5	567.67	567.67	113.53	3.88	0.011
	Year*Tret	5	593.56	593.56	118.71	4.06	0.009
	Error	22	643.17	643.17	29.23		
	Total	35	2189				
	R-Sq	=	70.62%				
BM	Rep	2	18441	18441	9220	6.96	0.005
	Year	1	0	0	0	0	1
	Tret	5	39807	39807	7961	6.01	0.001
	Year*Tret	5	1430	1430	286	0.22	0.952
	Error	22	29165	29165	1326		
	Total	35	88842				
	R-Sq	=	67.17%				
TKW	Rep	2	9.93	9.93	4.96	0.24	0.789
	Year	1	24.14	24.14	24.14	1.16	0.293
	Tret	5	197.06	197.06	39.41	1.9	0.136
	Year*Tret	5	125.16	125.16	25.03	1.21	0.339
	Error	22	456.75	456.75	20.76		
	Total	35	813.03				
	R-Sq	=	43.82%				
	Source	DF	SeqSS	AdjSS	AdjMS	F	P

GYqtHa	Rep		2	345.01	345.01	172.5	5.86	0.009
	Year		1	20.55	20.55	20.55	0.7	0.412
	Tret		5	576.13	576.13	115.23	3.92	0.011
	Year*Tret		5	603.67	603.67	120.73	4.1	0.009
	Error		22	647.35	647.35	29.42		
	Total		35	2192.7				
	R-Sq	=		70.48%				
AdYiq/ha	Rep		2	266.8	266.8	133.4	5.84	0.009
	Year		1	15.6	15.6	15.6	0.68	0.417
	Tret		5	444.58	444.58	88.92	3.89	0.011
	Year*Tret		5	466.76	466.76	93.35	4.09	0.009
	Error		22	502.69	502.69	22.85		
	Total		35	1696.43				
	R-Sq	=		70.37%				
BMqt/Ha,	Rep		2	18453	18453	9227	6.96	0.005
	Year		1	0	0	0	0	1
	Tret		5	39794	39794	7959	6	0.001
	Year*Tret		5	1427	1427	285	0.22	0.952
	Error		22	29172	29172	1326		
	Total		35	88847				
	R-Sq	=		67.17%				
HI	Rep		2	52.74	52.74	26.37	1.39	0.27
	Year		1	6.93	6.93	6.93	0.36	0.552
	Tret		5	353.35	353.35	70.67	3.72	0.014
	Year*Tret		5	128.64	128.64	25.73	1.36	0.279
	Error		22	417.69	417.69	18.99		
	Total		35	959.34				
	R-Sq	=		56.46%				

ANNX 2 Correlation of characters

	GY (Qt/Ha)	BM	DE	DH	DM	GY (kg/p)	NET	NT	PHcm	PanL	Spikelet	TKW
ESH-3	54.2	245.1	6.5	66.0	88.0	53.8	857.0	1390.0	174.0	31.7	53.7	26.4
ESH-1	51.4	314.0	7.3	64.3	88.5	51.0	819.0	1534.0	175.7	29.5	57.4	29.6
Dakaba	50.5	279.6	7.7	71.8	96.8	50.2	791.0	1317.0	134.6	28.0	61.3	26.2
ESH-4	46.8	208.9	7.5	68.5	92.7	46.5	883.0	1514.0	131.1	34.4	63.0	28.0
Melkam	46.2	258.5	8.7	70.5	92.0	45.8	655.0	1190.0	156.4	29.1	54.1	33.1
Teshale	42.0	285.6	6.3	67.2	88.7	41.7	963.0	1652.0	274.2	23.3	50.6	29.8
Gmean	48.5	265.3	7.3	68.1	91.1	48.2	828.0	1432.8	174.3	29.3	56.7	28.8
CV	15.3	15.5	19.3	4.4	4.1	15.3	13.9	14.5	4.6	12.9	9.8	4.0
LSD (5%)	8.8	48.6	1.7	3.5	4.4	8.7	136.2	245.9	9.4	4.5	6.6	5.3

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