Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.11, No.23, 2020

Evaluation of High Land Sorghum (Sorghum bicolor L. Meonch) Varieties for Yield Performance

Zigale Semahegn[1], Temesgen Teressa[1], Zewdu Asrat[1], Temesgen Begna[1], Workissa Yali[1], Hailu Gichele[1], Moges Mekonnen[1], Abdulfeta Tariku[1], Tamirat Bejiga[2]
1.Ethiopian Institute of Agricultural Research, Chiro National Sorghum Research and Training Center
2. Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center

Abstract
Despite of biotic and abiotic stress, the yield performance of crop varieties is affected by environment and Genotype by Environment interaction, which is the major challenge to plant breeders while developing improved varieties. In Ethiopia, high yielding, and stable varieties that withstand disease in the highland areas are limited. In view of this, the yield performance of nine sorghum varieties and one standard check were tested at three environments with the objectives of identifying the best performing and adapting varieties across environments. The experiment was conducted using Randomized Complete Block Design with Row Column arrangement and three replications. The combined analysis of variance across environments showed highly significant (P<0.001) difference among environments, genotypes and interactions for grain yield, days to flowering and plant height studied. Based on generalized linear model showed that variety Jiru, and variety Chiro and variety Dibaba were the high yielders, while variety Fendisha-1 and Variety Muyra-2 were the lower ones. From farmers' point of view, during evaluation based on their traits of interest (yield, plant biomass, head compactness, seed size, and seed color) variety Jiru was superior yield and adaptable, and therefore, recommended in the study areas. Generally, this study revealed the importance of evaluating released sorghum varieties for their yield and adaptability across diverse highland areas of Ethiopia.
Keywords: Sorghum, Analysis of Variance, Genotype by environment interaction
DOI: 10.7176/JNSR/11-23-03
Publication date: December 31st 2020

INTRODUCTION

Sorghum is the fifth most important cereal crop in the world (FAOSTAT, 2018). In Ethiopia, it ranks third in area coverage and production, after maize and teff and it is contributing 16.4% of the total annual cereal grain production (CSA, 2018). Currently sorghum is produced by 6 million holders and its production is estimated to be 5.2 million metric tons from 2.1 million hectares of land giving the national average grain yield of around 2.7 tons per hectare (CSA, 2018). In Ethiopia, sorghum provides food, fodder and alcoholic beverages. The main use of sorghum in Ethiopia is for making Injera. Due to the country is following mixed agricultural system, sorghum biomass has also almost equally importance as grain for animal feed, construction purpose and fuel wood.

However, the current rate of yield increment in sorghum is limited in Ethiopia. Even though, a number of biotic and abiotic factors contributed to the limiting grain yield increment, diseases are considered as one of the major biotic factors limiting sorghum productivity in the highland and intermediate areas of Ethiopia. These limitations are tackled by developing sorghum genotypes, which are more tolerant to leaf and grain diseases (Gebreyohannes *et al*., 2018). A challenge of sorghum production in the highland and intermediate parts of the country is lack of tolerant sorghum varieties to diseases, striga, stable and adaptable varieties, poor adoption of improved varieties by farmers, due to poor farmers participatory during selection (on-station) and inadequate knowledge of farmers about the varieties. Developing of tolerant varieties that can withstand biotic stress through introgression of resistant trait are the strategies being embedded in the sorghum breeding in Ethiopia.

Many findings have been reported on the performance of sorghum varieties in different agro-ecologies (Kinde *et al*., 2016; Fantaye and Hintsa, 2017; Amare *et al*., 2019, Zigale *et al*., 2019) and they reported the existence of the diverse performance and stability of the sorghum varieties across environments. Yield stability is one of the challenges facing plant breeders in developing broadly adapted with high yielder varieties (Asfaw, 2005). National sorghum research program, higher institutes and regional research centers were released more than sixty sorghum varieties, and from these ten varieties are released for the highland areas of Ethiopia. However, the released highland sorghum varieties were not evaluated and addressed in all highland areas of Ethiopia. Therefore, this study was conducted with the objective of identifying the best performing and adapting varieties across envirnments.

Materials and Methods

Description of the study area

The field experiment was conducted under rainfed conditions during the 2018 and 2019 main cropping season at two locations (Hirna and Alemata)), representing the highland areas of Ethiopia. Hirna station is located at 9^{o} 12'

N latitude, 41° 4'E longitude and at an altitude of 1870 m.a.s.l. The area receives mean annual rainfall ranging from 990 to 1010 mm. The average temperature of the area is 24.0°C. The soil of Hirna is vertisol (Haramaya University Research Center, 1996).

Genetic materials, experimental design and trial management

Planting materials (Table 1) used for the experiment consisted of eight sorghum varieties, which were released from national sorghum Research program and Haramaya University and single variety as a standard check. The trial was conducted using Randomized Complete Block Design with row column arrangement and three replications. The experimental plot consisted of 3 rows, each 5 m in length with 0.75 m between row spacing. The total area of each plot had a size of 11.25m^2.

As per the recommended rate for Sorghum production in the highland areas of Ethiopia, Both Di-ammonium phosphate (DAP) and urea were applied at the rate of 100 kg/ha. Diammonium phosphate was applied by incorporating into the soil during planting of the seeds, while urea was applied as side dressing at knee height stage after planting of the seed. Thinning was done after three weeks of planting to maintain the space between plants and to balance the plant density. Other crop management practices were done following the recommended practices. Days to 50% flowering, plant height (cm), grain yield per plot (GY) and converted to ha-1, days to 90% physiological maturity (DTM), plant aspect (PAS) data were collected and analyzed to identify stable and superior varieties compared with the standard check variety.

Using the raw data collected on days to flowering, maturity, overall plant aspect, plant height and grain yield of ten varieties, which were grown at two locations, analysis of data using generalized linear model under Genstat 17th ed. Software was computed; analysis of data using generalized linear model of RCBD with row column arrangement was computed. Before pooling the data over locations, Bartlett's test of homogeneity of variance was done for the traits to determine the validity of the overall analysis of variance of the data of combined locations. This analysis revealed the homogeneity of error variance. Therefore, overall analysis of variance was done to determine the effects of the genotypes, locations and their first order interactions using generalized linear model. Least significance difference was used to determine the significance of differences among the genotype means for days to flowering, maturity, overall plant aspect, plant height and grain yield.

Table 1: Description of sorghum genotypes tested at five two during 2018 and 2019 main cropping season

Entry	Genotype	Year of released	Breeder/Maintainer
1	Adelle	2016	Melkassa
2	Jiru	2016	Melkassa
3	Dibaba	2015	Melkassa
4	Chiro	1996	Melkassa
5	Chelenko	2005	Melkassa
6	ETS2752	-	Melkassa
7	AL-70	-	Melkassa
8	Fendisha-1	2015	Haramaya University
9	Muyra-1	2000	Haramaya University
10	Muyra-2	2000	Haramaya University

RESULTS AND DISCUSSIONS

The combined analysis of variance by generalized linear model of days to flowering, maturity, overall plant aspect, plant height and grain yield for ten varieties is presented in table 2. The result revealed that there were very highly significant ($p \leq 0.0001$) differences among sites, genotypes and interactions for grain yield, days to flowering and plant height (Table 2). This indicates that the high diversity of the growing conditions in the three environments and large variability in the varieties for grain yield, days to flowering and plant height. The very highly significant for Genotype by Environment Interaction is also showing inconsistencies in the performance of sorghum varieties across environments which show difference in the response of sorghum varieties at different environments. It means a breeder faces challenge of selection varieties for advancement, hence further evaluating of varieties with wider and specific adaptation and environments with good discriminating ability and representativeness is needed for further investigation. This result (especially for grain yield) is in agreement with the finding of Abiy and Firew (2016); Asfaw (2007); Zigale *et al.* (2019); Amare *et al.* (2019); Worede *et al.* (2020) observed significance difference of genotype, environment and genotype by environment interaction for days to flowering, plant height and grain yield. However, the result showed that there were only very highly significant differences among genotypes and interactions, while there were significant differences among environments for days to flowering and overall plant aspect.

Table 2: Analysis of variance of highland sorghum varieties on mean days to flowering, days to maturity, plant height, overall plant aspect, grain yield (kg/ha) by generalized linear model tested at two locations during 2018 and 2019 main cropping season

Sources of variation		Mean square				
	DF	GY	DTF	DTM	PHT	PAS
Genotype	9	15361265**	304**	66.7ns	1991.6**	2.6**
Environment	2	10400388**	39936.6**	1238**	158986.7**	2.2ns
Genotype:Environment	18	4685081**	174.1**	54.4ns	858.8**	1.7**
Replicate/ Environment	6	932557ns	13.4	21.1ns	1685**	0.1ns
Error	53	516869	68.5	48.4	352	0.5
Total	88	3140603	1016.5	70.8	4275	1

Performance of the genotypes

The mean values of the sorghum varieties for the traits considered are depicted in Table 3. Jiru and Fendisha-1 were the highest and least-yielding varieties with the yield of 5385.3 kg/ha and 1535.7 kg/ha, respectively. This showed the presence of cross over interaction across the testing locations. In general, ranking of varieties changed from one environment to another, indicates that, a remarkable Genotype by Environment and require further study to understand the patterns of interactions. This result is similarly reported by Zigale *et al.* (2019); Amare *et al.* (2019); Chalachew and Zigale (2019); Worede *et al.* (2020). With regards to overall plant aspect, Jiru (2.4) was better comparatively high attributes of seed color, seed size, threshability, panicle shape, disease and insect and lodging tolerance, good biomass.

When the grand mean values of the three environments were compared, 19AL (6823 kg/ha) followed by Chiro (6544 kg/ha) had higher sorghum grain yield, while 19HN (1244 kg/ha) had the smallest sorghum grain yield. Environments 19AL and 19HN could, therefore, be regarded as the highest and the lowest yielding environments, respectively. Jiru (6823 kg/ha) and Muyra-2 (1244 kg/ha) were the highest and least yielding varieties on the high and low yielding environments, respectively (Table 3). This result is in agreement with the finding of Zigale *et al.* (2019); Amare *et al.* (2019); Chalachew and Zigale (2019); Worede *et al.* (2020) were reported the highest and least yielding varieties on the high and low yielding environments.

Table 3: Mean grain yield (kg/ha) of 10 sorghum varieties across three environments.

		Environments			
Entry	Varieties	19HN	18HN	19AL	Mean
1	Adelle	4326	4622	2624	3857.3
2	AL-70	2930	4859	2403	3397.3
3	Chelenko	2444	5481	2249	3391.3
4	Chiro	2989	4741	6544	4758
5	Dibaba	4128	6430	1895	4151
6	ETS2752	4340	4178	3611	4043
7	Fendisha-1	1391	1642	1574	1535.7
8	Jiru	3911	5422	6823	5385.3
9	Muyra-1	1444	1481	2869	1931.3
10	Muyra-2	1244	1452	2140	1612
	Mean	2915	4031	3273	3406.2
	LSD (0.05)	260.4	1886	461	869.1
	CV (0.05)	9.5	27.3	15	17.3

Where, 19AL = 2019 Alemata, 19HN = 2019 Hirna, 18HN = 2018 Hirna, LSD = Lease significance difference, CV = Coefficient of variation.

Table 4: Mean grain yield and other agronomic traits of sorghum varieties evaluated at three environments.

Variety	DTF	DTM	PHT	GY	PAS
Jiru	149.4	217.9	357.8	5385.3	2.4
Dibaba	158.5	222.9	361.7	4151.0	2.7
ETS2752	150.1	212.7	346.8	4043.0	2.8
Adelle	159.2	218.8	367.3	3857.3	2.8
Chiro	152	215.9	328.9	4758.0	3.2
AL-70	154.6	220	336.8	3397.3	3.7
Fendisha	163.1	225.3	355.2	1535.7	3.7
Chelenko	154.2	217.4	345.8	3391.3	3.9
Muyra-1	158	219.6	320.9	1931.3	4.0
Muyra-2	167.9	218.9	355.5	1612.0	4.4
Mean	155.1375	218.8625	350.0375	3406.2	3.2
LSD (0.05)	7.9	8.2	17.7	869.1	0.9
CV (0.05)	5.3	3.2	5.4	17.3	21.1

Where, DTF = Days to flowering, DTM = Days to maturity, PHT = Plant height, GY = Grain yield and PAS = Overall agronomic plant aspect.

CONCLUSION

The combined analysis of variance showed the studied sorghum varieties were significantly different in most traits measured. The finding of this study showed that Jiru (5385.3 kg/ha), Chiro (4758.0 kg/ha), Dibaba (4151.0 kg/ha) had good yield performance, high plant biomass and very good overall agronomic desirable traits (seed color, head compactness, grain size, shape and thresh ability) over the standard check AL-70, while yields of other varieties reduced due to low yield potential.

Generally, from farmers' preference, during evaluation based on their traits of interest (yield, plant biomass, head compactness, seed size, and seed color) and results obtained from the experiment, it was showed that the present study entails the presence of significant variation in sorghum yield increment. Therefore, the sorghum variety, Jiru was identified as superior for grain yield and adaptable in the study areas.

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