Performance Evaluation of Sorghum (Sorghum bicolor (L.) Moench) Varieties in the Lowlands Area of Wag Lasta, North Eastern Ethiopia

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Abstract

Eight released sorghum varieties were evaluated in four environments in the Wag-himra and Lasta in main production season for two years (2016 and 2017). The objective of the trial was to identify high yielder sorghum varieties that possesses farmers preferred traits for production in both testing sites . The trial was conducted using a randomized complete block design with three replications. The GGE statistical model was used for analyzing genotype by environment interaction GEI and to assess the stability of sorghum variety for grain yield. A combined analysis of variance for grain yield and yield related traits showed that the main effects of both genotypes and environments, and the interaction effect, were highly significant ($P \leq 0.001$). The mean values of grain yield ranged from 1300 kg ha-1 (Dagim) to 2800 kg ha-1 (Melkam) with the overall mean values of 2100 kg ha-1. Based on the GGE biplot analysis, high yielding variety Melkam (2800 kg ha-1) showed better performance stability across the test environments. In addition, the result of participatory variety selection (PVS) revealed that Melkam ranked first and second preferred sorghum variety in Lasta and Waghimira agro-ecologies, respectively. We recommend, therefore, Melkam for production in both agro-ecologies and similar areas of the country. This variety will play a role in enhancing farmers' income through improved grain yield, especially in the dry lowlands areas of Wag-himra and Lasta.

1. Introduction

Sorghum (*Sorghum bicolor*(L.)Moench.) is an important cereal, particularly in the world's semi-arid tropics. It is a major food crop in sub-Saharan Africa and South Asia and is the staple food for the most food insecure people in the world (Bibi *et al*., 2010). It is the world's fifth most important cereal, after wheat, rice, maize and barley (FAO, 2010). More than 105 countries in Africa, Asia, Oceania and the Americas grow sorghum on 40 million hectares (Kumar *et al*., 2011), and 60% of this land is in Africa (FAO, 2008), where it continues to play an important food security role (Mutegi *et al*., 2011). Ethiopia is the primary center of origin and diversity for sorghum (Doggett 1988; Firew, 2006). It is widely distributed throughout Ethiopia and it is the most important cereal in the lowland areas because of its drought tolerance (Kebede, 1991).

Sorghum is the most importat crop in moisture deficit areas of eastern Amhara(CSA, 2017).The crop is used in various ways. The grain is used as whole flour mostly for processing injera.The flour is also used for the preparation of kita (non-fermented unraised bread or unleavened bread) and local alcoholic drinks. Besides the grain, sorghum straw is an important feed for livestock. However, the productivity of sorghum is low (15 kg/ha) in Wag-himra (CSA, 2017). This low productivity is mainly due to drought, poor soil fertility and lower yielding varieties.

Because of the significance of sorghum for food security in the drought prone areas, the development of early maturing varieties with reasonable yields have been a main focus of breeding programs in Ethiopia as well as in Sub-Saharan Africa (McGuire, 2005; Firew, 2006, Asfaw, 2007). For the past five decades, many early maturing sorghum varieties have been developed and released for lowland parts of Ethiopia by the Federal and Regional Agriculture Research Centers as well as Universities. Therefore, the objective of this study was to select high yielding and farmers preferred sorghum varietyes for the low land area of wag lasta.

2. Material and Methods

2.1. Plant material, experimental site and experimental design

Eight nationally and regionaly released sorghum varieties and a local check were evaluated during 2016 and 2017 the main cropping seasons at Aybera and Lalibela sites. Both testing sites represent the low land sorghum growing environments of the Waghimra and Lasta. Description of the experimental location and the sorghum varieties are presented in Table 1 and Table 2.

The experiment was laid out on Randomized Completely Block Design (RCBD) with three replications. Each variety was planted on a plot size of 18.75 m2 (5 m length by 3.75 m width), with an intra- and inter-row spacing

of 0.15 and 0.75 cm, respectively. Nitrogen and Phosphorous fertilizers were applied in the form of Urea and NPS at the rate of 41kgha⁻¹N and 46kgha⁻¹P2O5, respectively. All the recommended P2O5 and half of nitrogen were applied during planting whereas the remaining half of nitrogen was top-dressed at knee-height stage.

Table 1. Description of the experimental area used for evaluation of the sorghum varieties

Variable	Testing site	
	Aybra 2016 –2017	Lalibela 2016 –2017
Longitude	12^0 43, 38” N	11^0 58, 18” N
Latitude	79^0 01, 08” E	38^0 58, 54”E
Altitude meter above sea level	1915	1963
Average annual rainfall mm	492	769
Average maximum temperature C^0	26.9	24.7
Average minimum temperature C^0	15.4	13.6
Soil type	Vertisol	Vertisol

Table 2. Description the 9 sorghum varieties

No	Variety Name	Pedigree	Mantainer	Year of release
1	Melkam	WSV-387	MARC	2009
2	Dekeba	ICSR 24004	MARC	2012
3	Dagem	97MW6130	MARC	2011
4	Geremew	87BK-4122	MARC	2007
5	Chare	PGRC/E#222880	DBARC	2011
6	Mesay	Meko x Gobye	SARC	2011
7	Gambella	Gambella 1107	MARC	1976
8	Meko-1	M-36121	MARC	1997
9	Local check			

Abbreviation; Melkassa Agricultural Research Center (MARC), Sirinka Agricultural Rearch center (SARC) , D/Birhan Agricutural Reseach centr(DBARC)

2.2. Data collection and statistical analysis

Phenotypic data on quantitative traits were collected on plant and plot basis. Days to 50% heading (DH), and days to 90% maturity (DM) were measured on plots basis. Plant height (PH, in cm), head length (HL, in cm), and head weight (HW, in cm) were measured on five randomly selected plants per plot. Grain yield (GY; grams of grain produced per plot, which is later converted in kg/ha) and thousand seed weight(TSW) were measured on the plots basis as per IBGR and ICRISAT (1993).

Farmers' participatory varietal selection was conducted to select sorghum variety that possesses farmers preferred traits and farmers make selection on the four babay trials. The baby trials was a single replication and the farmers land which the baby is plannting is considering as a single replication. A total of 16 farmers (Men = 12, Women= 4) was participated in the participatory selection of sorghum variety at physiological maturity stage of the crop. Farmers listed the traits they used to evaluate a sorghum variety, which were ranked by importance. Each sorghum variety was evaluated by farmers based on the overall performance of each variety related to the three farmer traits including earliness, head length and seed color.

Analysis of variance was computed using SAS software v9.0 (SAS Institute, Cary, USA). Combined data analyses were computed after testing the homogeneity of error variances using Bartlett's test (Gomez and Gomez, 1984). Mean separation was carried out using least significant difference (LSD) at 5 percent level of significance. Genotype and genotype by environment interaction biplot analysis (Yan 2002) and correlation analysis were computed using GENSTAT software program 18ᵗʰ edition.

3. Result and Discussion
3.1. Grain yield and yield related traits

A combined analysis of variance for seven traits of the eight sorghum varieties and one local check tested across four environments is presented in Table 2. The analysis of variance for grain yield and yield related traits showed that the main effects of both genotypes and environments, and the interaction effect, were highly significant (P ≤ 0.001). This indicates that genotype, environment and their interaction are important in governing the expression of these traits. The significant genotype by environment interaction resulted either from differential responses of the variety to the test growing environments for these traits or changes in the relative ranking of genotypes. Asfaw (2008) in sorghum reported a similar result that showed a significant difference of genotypes, environment and genotype by environment effect for grain yield in dry hot lowlands of Ethiopia.

Table 2. Combined analysis of variance from nigh sorghum varieties for seven traits

Traits	Env (3)[†]	Var (8)	Env x Var (24)	Pooled error (64)	R-Square
DH	638.87**	1020.10**	114.34**	22.54	0.90
DM	2552.12**	431.18**	211.94**	84.00	0.76
PH	7375.84**	8566.08**	270.87**	178.05	0.90
HL	134.94**	185.24**	26.22**	7.07	0.85
HW	442208.46**	14973.84**	5617.37**	966.41	0.96
TSW	75.07**	317.75**	16.27^{ns}	9.75	0.84
GY	3996.15**	234.26**	38.52**	12.98	0.95

†   Numbers in parenthesis represent degrees of freedom , ns, *, **, = Non Significant , significant at P ≤ 0.05 and significant at P ≤ 0.01 respectively , Env= Environments , Var= Varieties , DH= Days to heading, DM = Days to maturity, PH = plant height (cm) , HL= Head length (cm) , HW= Head weight (gm), TKW = 1000 kernel weight (gm) ,GY= Grain yield (kg/ha)

The number of days to maturity combined over four environments ranged from 117 days (Meko and Melkam) to 132 days (Geremew) with an average day of 123. The mean values of head length ranged from 17 cm (Chare) to 28 cm (Dagim), with a mean of 22 cm.The mean value of thousand kernel weight ranged from 18 gm (Geremew) to 31 gm (Meko and Mesay) with the average values of 26gm. The mean values of grain yield ranged from 1300 kg ha-1 (Dagim) to 2800 kg ha-1 (Melkam) with the average values of 2100 kg ha-1. The result shows that there is a reduction in grain yield as compared to the national productivity of sorghum in Ethiopia, which is 25 kg ha-1(CSA, 2017), indicating the effect of moisture deficit on yield of sorghum at Wag–himra and Lasta is very important. In general, these areas are characterized by a highly unreliable rainfall with a limited amount and erratic distribution, which causes significant yield reduction and sometime total failure of sorghum in the areas (SDARC Annual Progress Research Reports for the period 2006/07 to 2014/15). Previous reports indicated that the major cause of grain yield reduction during moisture deficit is mainly associated with a reduction in grain size (Blum *et al.,* 1989, Yadav, *et al.,* 2003 in sorghum; Ozurk and Aydin, 2004 in wheat).

Table 8. Mean values of grain yield and yield related traits of sorghum varieties tested at four environments

No	Varieties	DH[@]	DM	PH	HL	HW	TSW	GY
1	Melkam	71	117	128	27	199	30	2800
2	Dekeba	83	124	109	21	186	23	2100
3	Dagim	95	130	118	28	98	19	1300
4	Geremew	91	132	119	25	150	18	1500
5	Chare	76	120	143	17	143	24	2200
6	Mesay	70	120	161	24	155	31	2400
7	Gambella	79	118	139	19	171	24	2000
8	Meko	69	117	146	21	141	31	2300
9	Local	83	130	196	18	216	30	2200
	Mean	80	123	140	22	162	26	2100
	C.V(%)	6	7	10	12	19	12	17
	LSD(5%)	3.87	7.47	10.88	2.17	25.35	2.55	2.94

@ refer to DH= Days to heading, DM = Days to maturity, PH = plant height (cm) , HL= Head length (cm) , HW= Head weight (gm), TKW = 1000 kernel weight (gm) ,GY= Grain yield (kg/ha)

The correlation among traits is presented in Figure 1. Grain yield had a positive and significant association with thousand kernel weight and plant height. This result agrees with previous studies by (Khizzah and Miller 1992; Kadam et al. 2002 and Aemiro *et al.,* 2017) in sorghum who reported a positive correlation between grain yield with plant height and thousand kernel weight. Significant association was observed in the following pairs of traits; days to heading with days to maturity and thousand kernel weight, plant height with thousand kernel weight and head length ; head weight with head length and thousand kernel weight. The presence of association is the indication that those traits are conditioned by the same set of gene, is it in the positive or negative direction (Falconer, 1989). Therefore, selection for one trait can indirectly introduce changes in the other trait in positive or negative direction due to either genetic linkage or the existence of a pleiotropic gene effect or both (Falconer, 1989).
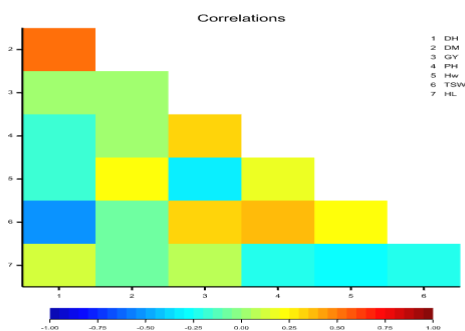
Figure 1.   Correlations among yield and yield related traits

3.2. Participatory variety selection (PVS)

Results of PVS showed that Local check was the least preferred variety in both testing sites (Data not shown), this indicates that the demand for improved variety of sorghum in the areas. At Lalibela site variety Melkam ranked first, followed by Dekeba and Geremew whereas, at Aybra site the highest rank value was recorded for variety Meko followed by Melkam and Dekeba. The reasons of the preference for these varieties were related to earliness, head length and seed color. Similar to farmers, researchers may use sorghum head related traits to predict the yield potential of a specific type of sorghum variety (Subba Redy and Rao, 1971; Blum et al., 1989; Haussmann et al., 1999; Aemiro et al., 2017). Several authors reported the importance of farmers involvement (PVS) in variety selection in order to use their indigenous knowledge for variety use related traits and share their traits preference (Gyawali et al., 2010 in rice; Demissew et al., 2013, in maize; Nkongolo et al., 2008, in sorghum; Mancini et al., 2017 in durum wheat). Joshi et al., (1995) reported that in addition to grain yield, farmers also consider other parameters like growing period, plant height, thresh ability, milling recovery, taste and other characters of rice.

3.3. Genotype and genotype by environment interactions biplot analysis for grain yield

GGE biplot based on PC1 and PC2 is indicated in Figure 2. Genotypes located at the vertices of the polygon performed either the best or the poorest in one or more locations since they had the longest distance from the origin of biplot (Yan and Kang, 2003). Accordingly, the vertex genotypes in this study were V1, V6, V4, and V3 which were the best or the poorest varieties in some or all of the environments because they were farthest from the origin of the biplot.

Polygon view of a biplot is most relevant to the investigation of the mega-environments and visualization of the which-won-where pattern of multi environment trial data (Yan et al., 2001) and it is important for studying the possible existence of different mega-environments in a region (Gauch and Zobel, 1997). V1 was high yielding variety at the first mega environment which contains the test environments; EV1, EV2 and EV3; the second mega environment contains Ev3 with V6 as the best yielder. The vertex variety V3 and V4 were not the top yielding genotypes in any environment. They were the poorly performing varieties with average grain yield below the grand mean. Genotype that fall in the central (concentric) circle is considered stable genotype (Yan, 2002). Genotype-focused comparison of genotypes revealed that genotype V1 fell in the central circle, was the ideal genotype in terms of higher yielding potential and stability, compared to the rest of genotypes evaluated in this study (Figure 3.). The GGE biplot analysis depicted V1 as stable variety.
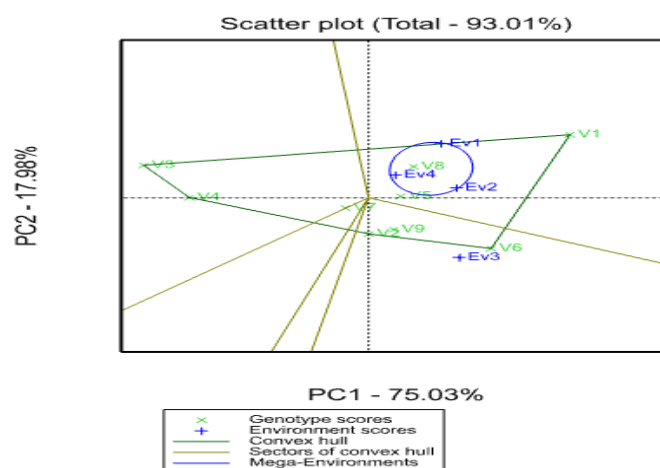
Ev1= Aybra 2008/2009; Ev2= Aybra 2009/2010; Ev3= Lalibela 2008/2009; Ev4= Lalibela 2009/2010; V1=Melkam; V2=Dekeba; V3=Dagim ; V4=Geremew ; V5=Chare ; V6= Mesay; V7=Gambella; V8=Meko; V9=Local .

Figiure 3. Polygon view of the GGE biplot show the "which-won-where" for 9 sorghum varieties over 4 test environments.
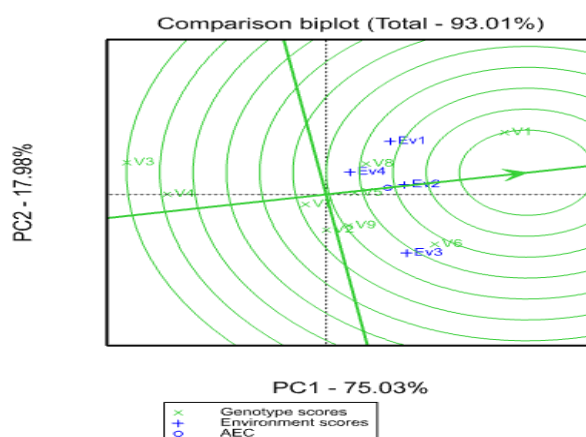

Figure 4 . GGE-biplot based on genotype-focused scaling for comparison the genotypes with the ideal genotype.

4. Conclusions and recommendations

Sorghum is one of the most dominant cereal crop both socially and agriculturally especially in the dry lowlands areas of Wag-himra and Lasta. Based on the GGE biplot analysis, high yielding variety Melkam (2800 kg ha-1) showed better performance stability across the test environments. Moreover, results of participatory variety selection (PVS) revealed that Melkam ranked first and second preferred sorghum variety in Lasta and Waghimira testing sites, respectively. For this reason, V1 (Melkam) is recommended for production in both testing sites and similar agro-ecologies of the country, for its yield, stability and seed color. This variety will play a role in enhancing farmers' income through improved grain yield, especially in the dry lowlands areas of Wag-himra and Lasta.

Acknowledgements

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