

Full Length Research Paper

Performance evaluation of sorghum [*Sorghum bicolor* (L.) Moench] hybrids in the moisture stress conditions of Abergelle District, Northern Ethiopia

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Received 17 November, 2016; Accepted 6 February, 2017

Sorghum [*Sorghum bicolor* (L.) Moench] grown under rain-fed conditions is usually affected by moisture stress at different stages, resulting in reduced yield. The assessment of variation in agronomic traits contributing towards drought escaping at these stages is of vital importance. This study was conducted during 2014 and 2015 cropping seasons using a randomized complete block design with three replications to evaluate 12 sorghum hybrids (one standard check) for their better performance under moisture stress conditions at Abergelle Agricultural Research Center on station. The data of 9 different agronomic traits were subjected to combined analysis of variance, estimation of genetic variability and heritability. Data was analyzed for variance for number of seeds per panicle, panicle length, plant height, days to flowering and maturity, 1000 seed weight, grain yield, biomass yield and harvest index under moisture stress conditions. The combined analysis of variance result for grain yield of the hybrids evaluated over seasons was highly significant at $p < 0.001$. Relatively high magnitude of phenotypic and genotypic coefficient of variations ($>20\%$) for grain yield, biomass yield and harvest index as well as high heritability ($>80\%$) for biomass yield were recorded. Generally, the present study entails the presence of significant variations among sorghum hybrids. Therefore, the hybrid sorghum genotypes Enforce (3263 kg ha^{-1}), NGC22319 (3113 kg ha^{-1}) and NGC76319 (3068 kg ha^{-1}) were identified as superior for grain yield under moisture stress conditions of Abergelle district.

Key words: Agronomic traits, grain yield, heritability, hybrid, moisture stress.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] belongs to the grass family, *Poaceae* which is among the dominant staple cereals for the majority of Ethiopians. It forms the most important dry land cereal crop for the semi-arid tropics together with maize and pearl millet (*Pennisetum glaucum* (L.). It requires less water than most cereals;

hence it offers great potential for supplementing food and feed resources (KARI Proceedings, 2000) especially in dry lands where rainfall is limited. Sorghum (*S. bicolor*) grows over a wide range of latitudes from 0 to 45° North and South of the equator (ICRISAT, 1991).

Plant moisture conditions are crucial to growth and

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development of plants. Under these stress conditions, the uptake of water by roots may be insufficient to meet the transpiration in such dry air and soil environments. rain fall (Geremew et al., 2004). It is a staple food in the drier parts of tropical Africa, India and China. Sorghum is grown in Ethiopia in 12 of the 18 major agro-ecological zones. It is one of the important indigenous food crops and is only second to *tef* as *injera* (leavened local flat bread) making cereal. The low land areas of Ethiopia are climatically characterized by high temperature and insufficient amount of rainfall during the crop-growing season. In these areas, crop production is mainly rain-fed. Because of the low amount, uneven distribution and erratic nature of the rainfall, crop production is seriously affected in these areas. A number of constraints have been standing on the way of sorghum production.

The major problems that check sorghum production in the dry land areas of the country include: lack of early maturing varieties that can escape drought, poor soil fertility, poor stand establishment due to reduced emergence in characteristically crusty soils, insect pests like the spotted stalk borers (*Chilo partellus*) and birds (Geremew et al., 2004). Sorghum grows in a wide range of agro ecologies most importantly in the moisture stressed parts of Ethiopia, where other crops can least survive and food insecurity is rampant (Asfaw, 2007).

Sorghum is one of the leading traditional staple food crops in Abergelle that acreage about 14335 hectares of land and this accounted for about 45.63%. It ranks first in its coverage in the district, but the area is often limited by moisture stress (Fantaye and Atsbha, 2016). Moisture stress is one of the most important abiotic problems/drought factors contributing significantly to yield loss in arid and semi-arid environments. This problem is alleviated by developing crops that are well adapted to moisture constraint areas. Sorghum is an important drought tolerant crop in such areas and is a good crop model for evaluating mechanisms of moisture stress. Over 80% of sorghum in Ethiopia, including Abergelle is produced under severe to moderate drought stress conditions. Most farmers grow long maturing local landraces, some of which take 7-8 months to mature further, complicating the drought problem. Although, the extent of yield loss due to drought was not studied in Ethiopia, complete yield loss was observed in some parts of the country, such as Mehoni area (EIAR, 2014).

In most of these areas, rainfall distribution is erratic and unreliable. Very short growing seasons are available for the crops grown in this part of the country. Consequently, only crop species which adapt to such short growing seasons are essential. The crops which are early maturing, drought tolerant and resistant to higher temperatures are of great interest to the farmers (Dereje et al., 1995). The national and regional sorghum improvement programs have released a number of open pollinated sorghum varieties for the moisture deficit lowland areas of Ethiopia. However, hybrids have been

found to be better suited than varieties to such stress environments as a result of earliness, better adaptation and stability (Yilma and Abebe, 1986).

Therefore, there is still need for development of more acceptable varieties/hybrids, which are high yielding, drought escaping, and are able to tolerate low soil fertility, pests and diseases in the moisture stress areas. Hence, this study was performed to evaluate sorghum hybrids for their yielding ability and estimate genetic variability and heritability under random moisture stress conditions of Abergelle district.

MATERIALS AND METHODS

Description of the study area

The field experiment was carried out under rain-fed conditions at Abergelle Agricultural Research Center (AbARC) testing site, during 2014 and 2015 cropping seasons, respectively. Abergelle is located in the central zone of Tigray National Regional State, Ethiopia (Figure 1). It is 903 km away from north of Addis Ababa and 120 km south west of Mekelle and situated at 13°14'06" N latitude and 38°58'50" E longitudes. The study area is identified as the most droughts prone in the region, where sorghum varieties released for drought tolerance by research institutions are tested and optimized (Georgis et al., 2010). The area is agro-ecologically characterized as hot warm sub-moist lowland (SMI-4b) located at an elevation of 1450 m above sea level. Plains, hills and river valley, characterize the topography of the district and it is highly exposed to soil erosion. Most soils of the district are dominated by sandy textured with poor water holding capacity and less fertile; in turn most of the crops failed to produce good yield (CSA, 2015).

The dominant soil types of the study area are small seedily called walka, bahkel, hutsa and mekayih. The rainfall status of the study area is unpredictable and erratic from season to season. The average annual rainfall varies from 350-650 mm and the temperature of the study area ranges from 18-42°C. The distribution of rainfall is erratic and variable, which results in strong variation in crop yields. The rain may start late and/or ends early. It is obvious that this kind of rainfall has a negative impact on the agricultural activities of the community causing uncertainty. The rainfall distribution from the agricultural point of view is mono-modal, concentrated during the summer (July to August). The farmers grow only one crop per season (Dereje et al., 2007).

Experimental design and crop management

The trial was laid out in randomized complete block design (RCBD) with three replications in a plot size of 11.5 m² (2.25 x 5 m). Experimental unit comprised of three-rows of 5 m length with row-to-row distance of 75 cm and plant-to-plant distance of 20 cm. Spacing between blocks and plots were 1 and 0.5 m, respectively. All plots were fertilized uniformly with 100 kg/ha diammonium phosphate (DAP) and 50 kg/ha urea. Full dose of P and half of N were applied at the time of planting and the remaining half was side dressed at knee height stage of the crop. Other management practices were applied as per recommendation.

Data collection and sampling techniques

Data were collected on some phenological (days to 50% flowering and 75% maturity), growth (plant height and panicle length), yield

Table 1. Mean values of morphological traits of sorghum hybrids tested at Abergelle on station.

Genotypes	Code	DM			PH			PL			NSPP		
		E1	E2	Mean	E1	E2	Mean	E1	E2	Mean	E1	E2	Mean
Liberty	H1	113	95	104 ^{abcd}	112.23	158.33	135.3 ^b	29.6	29.9	29.73 ^{ab}	2378	2130	2254 ^{abcd}
Dominator	H2	115	93	104 ^{abcd}	110.27	131.67	121.0 ^{cd}	27.42	23.9	25.64 ^c	2308	2224	2266 ^{abc}
Enforces	H3	109	94	102 ^{cde}	118.8	150.0	134.4 ^b	29.8	27.8	28.8 ^{bc}	2401	2258	2330 ^{ab}
NGC10341	H4	112	94	103 ^{bcd}	97.57	113.33	105.4 ^f	27.1	27.5	27.3 ^{cd}	2349	2423	2386 ^a
NGC58366	H5	119	96	108 ^{ab}	111.3	193.33	152.3 ^a	29.1	30.9	30.0 ^{ab}	2033	1984	1994 ^d
NGC05304	H6	112	95	104 ^{bcd}	132.07	178.33	155.2 ^a	30.73	30.7	30.73 ^a	2343	1919	2131 ^{abcd}
NGC10315	H7	124	94	109 ^a	99.63	123.33	111.5 ^{ef}	25.8	25.8	25.8 ^{de}	2258	2286	2272 ^{abc}
NGC22319	H8	104	94	99 ^{def}	114.42	133.33	123.9 ^c	28.62	27.4	28.01 ^c	1935	2217	2076 ^{bcd}
NGC76319	H9	111	93	102 ^{bcd}	111.93	135.0	123.5 ^c	29.13	26.3	27.73 ^c	2165	2230	2197 ^{abcd}
NGC41301	H10	104	91	98 ^{ef}	112.6	135.0	123.8 ^c	26.37	24.8	25.58 ^e	2072	2186	2129 ^{abcd}
NGC77344	H11	99	91	95 ^f	118.67	110.0	114.3 ^{de}	24.67	23	23.83 ^f	1953	2125	2039 ^{cd}
ESH-1 (check)	H12	117	97	107 ^{abc}	144.73	166.67	155.7 ^a	27.87	22.2	25.03 ^{ef}	2151	2395	2273 ^{abc}
LSD (5%)				7.56			11.97			2.21			383
CV (%)				4.5			5.6			4.9			10.6

Where, H=hybrid, E1= 2014 and E2= 2015 cropping seasons respectively; PH = plant height (cm), PL=panicle length (cm), DM = days to physiological maturity, NSPP=number of seeds per panicle, LSD = least significant differences, CV (%) = coefficient of variance.

and yield related traits of sorghum such as number of seeds per panicle thousand seed weight, grain yield, biomass yield and harvest index. Description of the traits investigated in this study includes: Days to 50% flowering, the date when 50% of the plants produced flowers was recorded and converted in number of days from date of emergence up to date of flowering; Days to 75% maturity, the date when 75% of the plants were physiologically matured; Plant height, plant height of tagged plants were measured from the ground level to the tip of the panicle at maturity and expressed in centimeter (cm); Panicle length, panicle length measurement (cm) from the base of the panicle to the tip from randomly selected plants per plot at maturity; Grain yield, total grain weight per plot (kg) after threshing then converted to kg per hectare. Biomass yield, the total sun-dry weight of the above ground biomass of the plants in the two middle rows (kg), then converted to kg per hectare; Number of seeds per panicle: Average number of seeds counted from 5 randomly selected plants' panicle in the plot; Thousand seed weight, the weight of one thousand seeds counted manually sampled from a plot and weighed at 12.5% moisture content. Harvest index, the ratio of grain weight to the total above ground biomass yield computed from the two middle rows.

Data analysis

The collected data were subjected to combine the analysis of variance (ANOVA) using the Statistical Analysis System (SAS) software version 9.1 program (SAS Institute, 2004). Means were separated using Fisher's Least significant difference (LSD) test at 5% level of probability as stated in Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Variation in grain yield and other agronomic traits

The combined analysis of variance revealed that the studied hybrids were significantly different in most traits

measured. The tallest mean plant height (155.2 cm) was attained in H6 (NGC05304) and the difference in height with the other hybrids was significant at $p < 0.001$. Moreover, H6 (NGC05304) had the tallest mean panicle length (30.73 cm) and the difference with the other hybrids was significant at $p < 0.05$ (Table 1). However, the shortest plant height (105.4 cm) and panicle length (23.83 cm) were recorded from H4 (NGC10341) and H11 (NGC77344), respectively. The difference in days to 50% flowering was statistically significant between NGC77344 and the other studied hybrids (Figure 2). NGC77344 had shorter days to 75% maturity. This shows that NGC77344 is a candidate hybrid for terminal drought prone areas, where the longest mean number of days to maturity (109) was recorded for NGC10315.

The earliness traits (days to flowering, grain filling period and days to physiological maturity) enables them to flower, grain fill and mature early. NGC77344 matured earlier than the other hybrids thus making it more adaptable in the moisture stress conditions of Abergelle district and other districts having the same agro-ecologies, but low yielder as compared to the other sorghum hybrids.

Highly significant ($p < 0.001$) varietal difference was observed for most of yield and yield related traits (Table 2). The mean total grain yields of the hybrids showed high variation in grain yield which ranged from 1844 (NGC58366) to 3263 kg ha⁻¹ (enforces). This result revealed that when there were more mean plant height and panicle length, the yield increased (Table 1). Farooq et al. (2009) also reported that grain yield is the result of the expression and association of several plant growth components. The combined analysis of variance indicated that among the 12 hybrids, Enforce (3263 kg

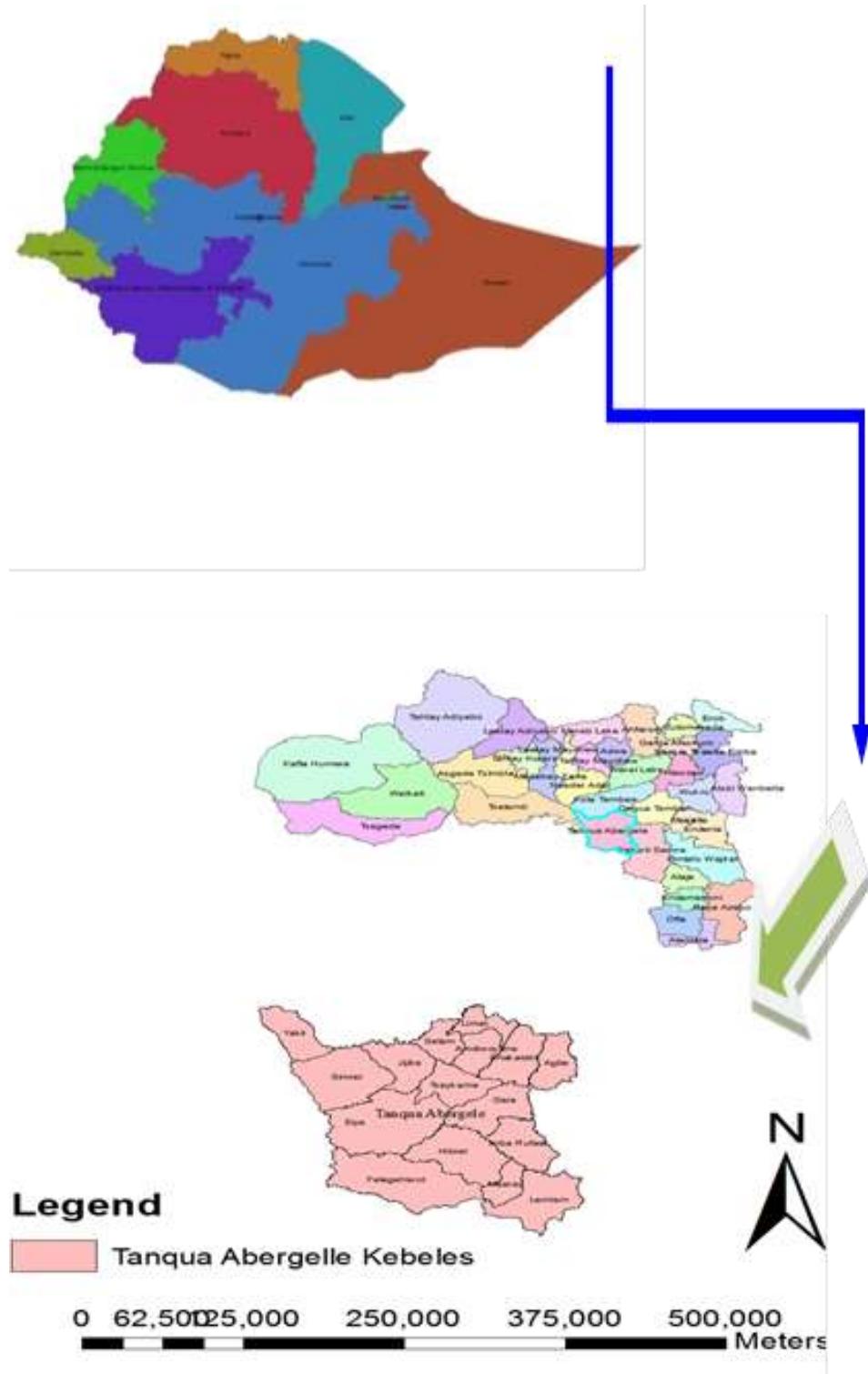


Figure 1. Map of the study area.

ha^{-1}), NGC22319 (3113 kg ha^{-1}) and NGC76319 (3068 kg ha^{-1}) had significantly ($p < 0.001$) higher grain yield than the commercial hybrid ESH-1 used as a check in Ethiopia. Besides, the results of the present study (Table

2) showed that the 11 hybrids had significantly ($p < 0.001$) higher biomass yield, thousand seed weight and harvest index than the check (ESH-1). The number of seeds per panicle ranged 1994 (NGC58366) to 2386 (NGC10341).

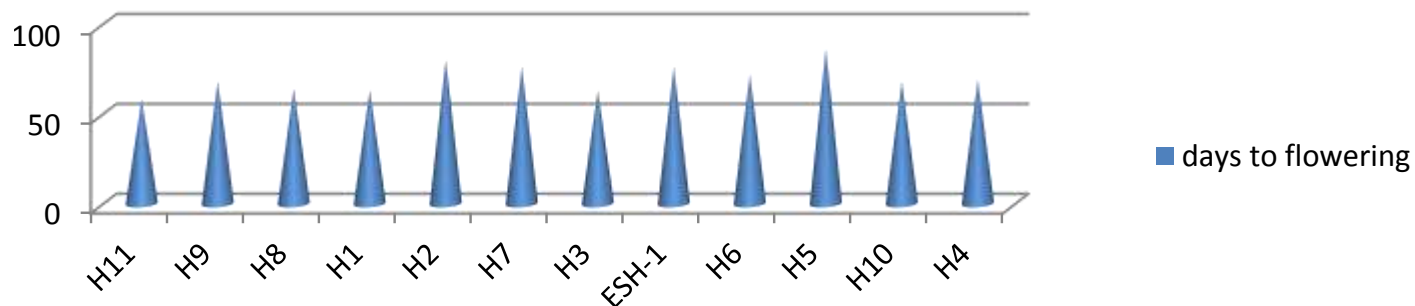


Figure 2. Days to 50% flowering of the studied sorghum hybrids during the main rainy season.

Table 2. Mean yield and yield related traits of sorghum hybrids tested at Abergelle on station.

Genotypes	Code	TSW			GY			BM			HI		
		E1	E2	Mean	E1	E2	Mean	E1	E2	Mean	E1	E2	Mean
Liberty	H1	20	22	21.00 ^{cd}	2115	3075	2595 ^{cd}	2588	3469	3028 ^{ef}	0.81	0.89	0.850 ^{ab}
Dominator	H2	19	23.7	21.33 ^{bcd}	2141	2277	2209 ^e	3439	3889	3134 ^{de}	0.66	0.81	0.733 ^{cd}
Enforces	H3	20.3	21.7	21.00 ^{cd}	2955	3570	3263 ^a	3331	3889	3610 ^{abc}	0.88	0.92	0.899 ^a
NGC10341	H4	19	20.3	19.67 ^{de}	1733	2650	2192 ^e	2102	2949	2526 ^g	0.84	0.89	0.864 ^a
NGC58366	H5	18.67	25.3	22.00 ^{bc}	1807	1881	1844 ^f	3601	2346	2974 ^{efg}	0.50	0.80	0.653 ^d
NGC05304	H6	22.3	24	23.17 ^{ab}	2869	2783	2826 ^{bc}	3296	3113	3205 ^{bcdde}	0.88	0.89	0.885 ^a
NGC10315	H7	17.3	18.7	18.00 ^e	1445	2853	2149 ^e	3067	3238	3152 ^{cde}	0.47	0.88	0.676 ^d
NGC22319	H8	23.3	20	21.67 ^{bc}	2304	3922	3113 ^a	2868	4412	3640 ^{abc}	0.81	0.89	0.848 ^{ab}
NGC76319	H9	20.3	22	21.17 ^{cd}	2747	3390	3068 ^{ab}	3683	3848	3766 ^a	0.76	0.88	0.819 ^{abc}
NGC41301	H10	22	21.7	21.83 ^{bc}	2283	2697	2490 ^d	2675	3073	2874 ^{efg}	0.86	0.88	0.868 ^a
NGC77344	H11	23.67	20.7	22.17 ^{bc}	2033	1995	2014 ^{ef}	2817	2480	2648 ^{fg}	0.74	0.81	0.773 ^{bc}
ESH-1 (check)	H12	20	29	24.50 ^{bc}	2101	3324	2713 ^{cd}	3286	3871	3578 ^{abcd}	0.67	0.81	0.765 ^{bc}
LSD (5%)				2.66			390.65			656.5			0.12
CV (%)				7.5			9.4			12.6			9.3

Where, H=hybrid, E1= 2014 and E2= 2015 cropping seasons respectively; TSW= 1000 seed weight (g), GY = grain yield (kg·ha⁻¹), BM = total biomass (kg·ha⁻¹), HI (%) = harvest index, LSD = least significant differences, CV (%) = coefficient of variance.

1000 seed weight ranged from 18.00g (NGC10315) to 24.50 g (ESH-1). The highest biomass yield was observed in NGC76319 (37.66 kg ha⁻¹) followed by NGC22319 (3640 kg ha⁻¹), whereas the lowest biomass yield was recorded from NGC10341 (2526 kg ha⁻¹). However, the newly evaluated hybrids did not differ significantly from ESH-1 in number of seeds per panicle. Generally, from farmers' opinion during field day and results obtain from the experiment the hybrids, Enforces, NGC22319 and NGC76319 took the first, second and the third places orderly in Abergele district.

Components of variability and heritability

The phenotypic and genotypic variance were estimated according to the methods suggested by Burton and de Vane (1953) and these components of variance (σ^2_p , σ^2_e and σ^2_g) were used for the estimation of coefficients

of variation (PCV, GCV) as described by Singh and Chaudhary (1977). Heritability (K=2.06 at 5% selection intensity) were computed for each character based on the formula developed by Allard (1960).

1. Genotypic variance, $GV = (MSg - MSe) / r$, where MSg = mean square of genotypes, MSe = mean square of error, and r = number of replications;
2. Phenotypic variance, $PV = GV + MSe$, where GV = genotypic variance and MSe = mean square of error;
3. Phenotypic coefficient of variation, $PCV = (\sqrt{PV}) / x \times 100$, where PV = phenotypic variance and x = mean of the character;
4. Genotypic coefficient of variation, $GCV = (\sqrt{GV}) / x \times 100$, where GV = genotypic variance and x = mean of the character;
5. Heritability (broad sense heritability), $H = GV / PV \times 100$ where GV and PV are genotypic and phenotypic variances, respectively.

Table 3. Estimates of means, genotypic and phenotypic variation, genotypic and phenotypic coefficients of variation for yield and yield related traits of hybrid sorghum genotypes.

Traits	Mean square			Mean	δ^2g	δ^2p	GCV (%)	PCV (%)
	Genotypes	G*E	Error					
	(df=11)	(df=11)	(df=44)					
Days to flowering	133.39	28.65	34.55	59.61	30.097	117.387	7.724	15.2543
Days to maturity	11.38	49.59*	21.16	102.8	46.45	80.2977	6.05	7.955
Plant height	42.79	725.03***	53.03	129.7	207.37	428.143	12.15	17.458
Panicle length	4.169	6.104*	1.813	27.4	2.084	4.8713	5.16	7.886
Number of seeds per panicle	8152	63663	54293	2196	12616.5	54429.7	5.135	10.665
Thousand seed weight	1.542	18.852***	2.614	21.5	14.315	17.955	17.63	19.745
Grain yield	345704	500763***	56497	2540	17.51	23.19	18.88	21.726
Biomass yield	1455729	845552***	159563	3178	107.36	122.36	33.07	35.307
Harvest index	0.0133	0.022***	0.0055	0.803	0.032	0.042	23.58	27.015

*Indicates significance at $P < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$. Where, G*E=genotype by environment interaction, δ^2p = phenotypic variation, δ^2g = genotypic variation, GCV (%) = genotypic coefficient variance, PCV (%) = phenotypic coefficient variance.

Mean, estimates of variance component coefficients of variation

A relatively high phenotypic coefficient of variation (PCV) values (>20%) were obtained for grain yield (21.73%), biomass yield (35.31) and harvest index (27.015%) (Table 3). Similarly, high genotypic coefficients of variation (GCV) values (> 20%) were also obtained for biomass yield (33.07%) and harvest index (23.57%). Bello et al. (2007) reported high value of PCV and GCV for panicle length per plant, 1000 seed weight, days to flowering and days to maturity (Kassahun et al., 2015), high PCV values (>20%) for leaf area index, plant height, panicle weight, panicle yield, grain yield and harvest index and relatively high GCV values (> 20%) for leaf area index, plant height, panicle yield, grain yield and harvest index. Tesfamichael et al. (2015) also reported high magnitude of phenotypic and genotypic coefficient of variations for plant height, harvest index and biomass. In contrast to the present study, low GCV and PVC (<20%) was observed in terms of panicle length, number of seeds per panicle, plant height, days to maturity, 1000 seed weight except grain yield, biomass and harvest index (Table 3). In another case, the study indicated that improvement of these traits through selection is less effective due to lack of genetic variation among the genotypes which is the basic prerequisite in which positive response due to selection depends on.

According to Singh (2001), high heritability of a trait ($\geq 80\%$) provides selection for such traits which could be fairly easy due to a close correspondence between the variety and the phenotype due to the relative small contribution of the environment to the phenotype. In other words, if environmental variability is small in relation to genotypic differences, selection will be efficient because the selected character will be transmitted to its progeny.

Based on this idea, high broad sense heritability was estimated for only biomass yield (87.74).

Conclusions

According to the combined analysis of variance, the studied hybrids were significantly different in most traits measured. The findings of this study showed that H3 Enforces (3263 kg ha⁻¹), NGC22319 (3113 kg ha⁻¹) and NGC76319 (3068 kg ha⁻¹) had a good performance while yield of other hybrids reduced due to low yield potential, which were sensitive to stress conditions than the check (ESH-1). The earliness traits (days to flowering, grain filling period and days to physiological maturity) enables them to flower, grain fill and mature early. Relatively, high magnitude of phenotypic and genotypic coefficient of variations (>20%) for grain yield, biomass yield and harvest index as well as high heritability (>80%) for biomass yield were recorded.

Generally, from farmers' opinion, during field day and results obtain from the experiment, it was revealed that the present study entails the presence of significant variation in sorghum yield increment. Therefore, the sorghum hybrids Enforces, NGC22319 and NGC76319 were identified as superior for grain yield under random moisture stress conditions of Abergelle district.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank Abergelle Agricultural Research

Center for funding the research work. They also express their great gratitude to researchers of the center by devoting their time to support this work.

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