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Research Article

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Genetic Variation in Dry Lowland Sorghum Landraces of Abergelle, Northern Ethiopia

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Abstract

Even though sorghum is dominant cereal crop in Tigray region of Ethiopia, a limited study has been undertaken on existing sorghum landraces variability. Thus, the objectives of this study were to assess the presence and degree of variability among fifteen sorghum landraces for desired agro-morphological traits at Abergelle Agricultural Research Center, northern Ethiopia during 2020 cropping season. The field experiment was conducted in randomized complete block design (RCBD) with three replications. Data were collected and analyzed variance for days to emergence, days to flowering, days to maturity, plant height, panicle length, number of seeds per panicle, thousand grain weight, grain yield and striga count at harvesting of sorghum under random stress conditions. Analysis of variance revealed significant genetic difference among sorghum landraces for most of the traits measured. Based on mean performance the genotypes Birle (3750 kg ha^{-1}), Woitozira (3500 kg ha^{-1}), Tewzale (3260 kg ha^{-1}), Daka (3000 kg ha^{-1}) and Amsel (2700 kg ha^{-1}) were found superior over check variety Chare. The phenotypic coefficient of variation (PCV) had exceeded the genotypic coefficient of variation (GCV) for all the variables studied, suggesting certain degree of interaction with the environment. Moreover, high heritability coupled with high genetic advance as percent of mean (GAM) were recorded for grain yield, panicle length, number of seeds per panicle, thousand grain weight and plant height, reflecting the presence of additive gene action for the expression of these traits and improvement of these traits could be done through selection. In conclusion, the high yield performing of sorghum landraces screened in this study could be exploited as source of breeding materials for further sorghum improvement to enhanced grain yield.

Keywords: Agro-morphological traits; Grain yield; Heritability; Landraces; Variability

Introduction

Sorghum [Sorghum bicolor (L.) Moench 2n=2x=20] belongs to the grass family Poaceae is the fifth most important crop in the world and is among the dominant staple cereals for the majority of Ethiopians. It ranks 4th in Ethiopia in terms of total production (45.2 million quintal), area cultivated (1.7 million hectare), and number of farmers (4.3 million) producing the commodity (CSA, 2020). Oromia and Amhara regions are the highest sorghum producers (76%) followed by Tigray region, ranked third next to Oromia and Amhara in terms of area coverage and production in the country. Sorghum grows in 12 of the 18 major agro-ecological zones most importantly in the moisture stressed areas of Ethiopia, where other crops can least survive and food insecurity is rampant (Asfaw, 2007) [1].

Sorghum is a staple food for more than 500 millions of people in Sub-Saharan Africa and Asia (Mace et al., 2013. Sorghum grain is utilized in various ways. Sorghum flour (fermented or unfermented) is used for human food such as breads, porridges, couscous, and snacks and beverages. The grain and fresh or dry biomass has diverse use and good source for sugar, syrup, and molasses industry (McGuire, 2007). It is also the second most important crop for injeraquality next to tef in Ethiopia. In addition, sorghum stalks and leaves are an important source of dry season feed for livestock, source of energy for cooking their daily foods, for construction of houses and fences, and as fuel wood (MoA, 2010) [2].

Ethiopia is believed to be center of origin and diversity for sorghum (House, 1985; FAO, 1995), which indicates the availability of extremely rich genetic diversity in sorghum landraces (Shegro et al., 2012; Girma et al., 2020; Mamo et al., 2023). Ethiopian farmers grow with over 95% of the area allocated for sorghum production covered by landraces (Asfaw, 2014) [3]. As a result, the Ethiopian sorghum landrace collections have been used as a main sources of several genes for important agronomic traits (Tesfaye et al., 2016) in many national and international sorghum breeding programs. Landraces are the varieties nurtured and cultivated by the farmers through traditional method of selection over the decades. An autochthonous landrace is a variety with a high capacity to tolerate biotic and abiotic stress, resulting in high yield stability and an intermediate yield level under a low input agricultural system (FAO, 1998) [4].

Characterizing morphological diversity is a valuable method for identifying landraces that possess desirable traits, such as early maturity, disease resistance or enhanced grain qualities. Although there is high genetic variability/diversity of sorghum in Ethiopia, inadequate research attention was given among locally available sorghum landraces in Tigray region specifically in the dry lowland areas of Abergelle. Thus, the current study attempted to assess the genetic variability and heritability of plant attributes in different sorghum landracess that contribute to grain yield [5].

Materials and Methods

Description of the study area

A field experiment was conducted at Abergelle Agricultural

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Research Center on station in the Central zone of Tigray region, Ethiopia during 2020 cropping season. The research station is situated at latitude of 13014 06 N and longitude of 38058 50 E at an elevation of 1560 meter above sea level (m.a.s.l) in Abergelle district. The area lies as hot warm sub-moist lowland (SMl-4b) agro-ecology classification with semiarid climate which is almost hot and dry throughout the year. Sorghum and Cowpea are dominantly cultivated crops because of their adaptation potential. The annual rainfall and temperature of the study area ranges from 300-600 mm and 18-41oC, respectively, which is characterized by uneven erratic distribution and variable results in strong variation in crop yields. The soil texture of research site is sandy clay with neutral (7.12) pH and high (22.6 %) CEC, low (0.08) nitrogen content and high available phosphorus [6].

Experimental materials, design and field management

The experimental plant materials comprised of 15 sorghum local landraces along with one standard check. The landraces were collected from farmers field at maturity of sorghum from dry lowland areas of Abergelle-Temben, central Tigray of Ethiopia. The planting materials were evaluated in a randomized complete block design (RCBD) with three replications. Each entry was planted in a plot having 5 rows of 5meter length with row-to-row distance of 75cm and plant-to-plant distance of 20cm [7]. The three middle rows were harvested and two border rows were left to exclude border effect. The gross area of experimental plot and the harvestable area had a size of 18.75 m2 (3.75 m x 5 m) and 11.25m2 (2.25 m x 5 m), respectively, separated by a distance of 1.5 m between replications. Each experimental plot was fertilized uniformly with NPSZnB (100 kg/ha) blended fertilizer applied at the time of planting and Urea (50 kg/ha) was side dressed when the crop reached at knee height. All other agronomic practices were applied as per the recommendations for sorghum in the study area (Table 1) [8].

Data collection and sampling techniques

Data of some phenological (days to emergence, days to flowering, days to maturity), morphological (plant height, panicle length) and yield and yield related traits (Grain yield, thousand grain weight, number of seeds per panicle) of each entry was collected. Measurements and observations were recorded following the IBPGR/ICRISAT (1993) descriptor list. For single plant based traits, mean value of five plants were tagged randomly before the time of data collection [9].

Data collected on plant bases

- **Plant height (cm):** This was determined from the base of the stalk at ground level to the tip of the head.
- **Panicle length (cm):** Measured from the base of the panicle to the tip of the panicle at maturity.
- Data collected on plot bases
- **Days to emergence:** The number of days from the date of sowing to the date at which 50% of the seedlings in a plot were emerged.
- **Days to flowering:** The number of days from planting to the date at which 50 % of the plants in a plot started flowering.
- **Days to maturity:** The number of days from planting to the date where 90% of the plant matured on which seeds on the lower part of panicle formed black layer.
- **Grain yield (kg ha^{-1}):** The panicles from the three rows of each plot were threshed, cleaned and adjusted to standard moisture level at 12.5% and weighted to get the grain yield per plot in grams and converted to kg ha^{-1} for analysis.
- Thousand grain weight: The weight of 1000 randomly sampled grains from each plot was measured in grams using sensitive balance and adjusted at 12.5% moisture content.
- Number of seeds per panicle: Average number of seeds counted from 5 randomly selected plants'panicle in the plot.

Data recorded on striga hermonthica weed

Striga count at harvesting: This was recorded as the number of striga count per each plot at harvesting of sorghum

Data analysis

The collected data (agro-morphological and sriga count) were subjected to analysis of variance (ANOVA) using GenStat 16th edition (GenStat, 2014) software following a procedure appropriate to RCBD (Gomez and Gomez, 1984). Mean separation was done using Fisher's least significant difference (LSD) test at 5% level of significance.

Table 1: Descriptions of the genetic materials used in the study.

S №	Local name	Collection year	Collection area	Status	Maturity group	Days to flowering	Plant height group	Races	Seed color
1	Chibal	2019	Abergelle	Landrace	Medium	89	Tall	Caudatum	Red
2	Woitozira	2019	Abergelle	Landrace	Medium	84	Tall	Dura	White
3	Chare	Check	DBARC	Improved	Early	78	Short	Bicolor	White
4	Abebe	2019	Abergelle	Landrace	Medium	81	Tall	Dura	Red
5	Alaela	“	“	“	“	91	“	Dura	Yellow
6	Buwa	“	“	“	“	90	“	Caudatum	Yellow
7	Amsel	“	“	“	“	84	“	Dura	White
8	Atish	“	“	“	“	83	“	Caudatum	White
9	Birle	“	“	“	“	82	“	Dura	White+scattered red
10	Tewzale	“	“	“	“	84	“	Caudatum	Red
11	Kodon	“	“	“	“	85	“	Dura	Chalky
12	Daka	“	“	“	“	92	“	Dura	White
13	Merawi	“	“	“	“	90	“	Caudatum	Chalky
14	Minaba	“	“	“	“	89	“	Dura	White
15	Mitswa	“	“	“	“	91	“	Caudatum	White

Note: DBARC = Debre Birhan Agricultural Research Center; Maturity group: early <120 days; medium: 121- 150 days; late: >151 days (local area classification); Height group

Variability among landraces were estimated using genotypic variances and coefficients of variations as suggested by Burton and De vane (1953) and these components of variance (δ2p, δ2e, δ2g) were used for the estimation of coefficients of variation (PCV, GCV) as described by Singh and Chaudhary (1985). Broad sense heritability (H2) and genetic advance as percent of mean (GAM) were calculated based on the method suggested by Johnson et al. (1955) [10].

- Genotypic variance, GV=, where MSg = mean square of genotypes, MSe = mean square of error (environmental variance or δ2e), and r = number of replications;
- Phenotypic variance, PV = GV +MSe, where GV = genotypic variance and MSe = mean square of error;
- Genotypic coefficient of variation, GCV =, where GV = genotypic variance and x =grand mean of the character;
- Phenotypic coefficient of variation, PCV =, where PV = phenotypic variance and x = mean of the character.
- Broad sense heritability (H2) of all traits was calculated according to the formula as described by Allard (1960) as follows: H2 = [(σ2g) / (σ2p)] × 100, where σ2g and σ2p are genotypic and phenotypic variances respectively [11].
- Genetic advance (GA) for selection intensity (K) at 5% was computed according to Allard (1960) as given here: GA = K x (√σ2p) x σ2g/σ2p, where, GA = expected genetic advance, K = the standardized selection differential at 5% selection intensity (K = 2.063), where σ2g and σ2p are genotypic and phenotypic variances respectively.
- Genetic advance as percentage of population means (GAM) was also estimated with the methods described by Johnson et al. (1955) to compare the extent of the predicted advance of different traits under selection using the following formula: GAM= , where GA = genetic advance under selection and x = mean of the population.

Results and Discussion

The results of analysis of variance for eight traits are presented. The genotypes revealed highly significant ($P<0.01$) differences for all the traits studied except days to emergence, indicated that the existence of variation among the sorghum landraces for the studied traits. In agreement with this finding, many authors (Wondewosen and Tekle, 2014; Gedifew and Tsige, 2019; Tamirat et al., 2021; Habtamu and Habtamu, 2022; Jafar et al., 2023; Yemane et al., 2024) have reported existence of genetic variability for days to flowering, days to maturity, plant height, panicle length and thousand grain weight in Ethiopian sorghum landraces [12].

Mean performances of sorghum genotypes

Days to flowering and maturity are the most important attributes that need to be considered in selecting genotypes for semi-arid drought prone areas like Abergelle. In this study, the number of days to flowering ranged from 78 for Chare to 92 for Daka. The variation of entries for days to maturity ranged from 117 to 149 days with a mean of 138.40 days. Chare was early maturing variety with 117 days followed by the medium maturing (128 days) landrace Birle where Mitswa was late that took longer time (149 days) to mature. The result indicated that there was a genetic variation among tested sorghum landraces for earliness traits. The landrace with the tallest plant height was Alaela with 300 cm, whereas the check variety (Chare) recorded the shortest plant height (170 cm). All of the local landraces were taller than the standard check. The landrace with tallest panicle length was Tewzale with 35 cm, while the shortest was Minaba with 12 cm and the difference with the other landraces were significant at $P\leq 0.01$ [13].

The result of the present study also revealed significant differences for number of seeds per panicle (NSPP) ranged from 1358 to 2616 with mean of 1966.9. The highest NSPP was recorded from Tewzale (2616) followed by Birle (2448) and Woitozira (2312), whereas the lowest NSPP was recorded from Minaba (1358). The overall average thousand grain weight (TGW) of the landraces was 31.4g. The genotype Birle scored the highest TGW (37g) followed by Woitozira and Tewzale with TGW (36, 34), respectively, while Minaba recorded the smallest TGW (25g) [14].

The average mean grain yield of landraces was 2460 kg ha^{-1}. Birle (3750 kg ha^{-1}), Woitozira (3500 kg ha^{-1}), Tewzale (3260 kg ha^{-1}), Daka (3000 kg ha^{-1}) and Amsel (2700 kg ha^{-1}) were found the best sorghum landraces that yielded above average and gave better grain yield than the check variety Chare (2520 kg ha^{-1}) , while the lowest yield was attained from Minaba (1300 kg ha^{-1}). Thus, it can be concluded that the low yielding landrace Minaba had lower NSPP, shorter PL and lighter TGW while the high yielding landraces Birle, Woitozira, Tewzale, Daka and Amsel had high NSPP, long PL and heavy TGW which implies that grain yield linearly associates with panicle length, number of seeds per panicle and thousand grain weight are indicators for varietal yield performance. Similarly, Yemane et al. (2024) reported that grain yield increased as the yield attributed traits, such as panicle length and panicle weight increased.

Besides, the analysis of variance result exhibited a significant ($P\leq0.01$) difference among landraces in reaction to Striga infestation. The smallest number of striga counts per plot (5, 6, 7, 8) at harvesting of sorghum were recorded from Abebe, Alaela, Minaba and Birle, respectively, while the highest number of Striga count per plot (120) was recorded from the sorghum landrace Chibal. This result concurred with the finding of Mesfin et al. (2014) who reported variability in sorghum responses to striga infestation (Table 2) [15].

Variability estimates of quantitative traits

The mean squares and estimates of phenotypic (σ2p), genotypic (σ2g) and environmental (σ2e) variances, phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) along with the mean of traits investigated are presented in. The analysis of variance showed that the mean squares for the genotypes were highly significant ($p<0.01$) for all characters, indicating presence of adequate variability among sorghum landraces. The genotypic coefficient of variation (GCV) was less than its corresponding estimates of the phenotypic coefficient of variation (PCV) for all the traits studied, suggesting certain degree of interaction with the environment. The GCV and PCV values are normally categorized as low (<10%), moderate (10-20%) and high (>20%) as indicated by Deshmukh et al. (1986).

High phenotypic and genotypic coefficient of variation values (>20%) were attained for grain yield (27.8%, 27.6) and panicle length (24.1, 23.8%), implying selection for these traits will be effective due to presence of a high amount of variability and thus the phenotypic selection of these traits would be rewarding. In harmony with the findings of Kassahun et al. (2011) who found high PVC and GCV for plant height, panicle length and grain yield.

Moderate phenotypic and genotypic coefficient of variation values (10-20%) were recorded for number of seeds per panicle (17.7, 17.4), thousand grain weight (16.9, 16.6) and plant height (11.8, 11.6), which

Table 2: Mean performance of growth, phenological, yield component traits and striga count at harvesting of sorghum landraces at Abergelle in 2020 cropping season.

Landraces	DE	DF	DM	PH	PL	NSPP	TGW	GY	SCPP
Chibal	6	89^{b}	145^{b}	235^{h}	21^{e-g}	1687^{f}	32^{e-g}	2187^{ij}	120^{a}
Woitozira	7	84^{cd}	134^{d}	265^{d-f}	23^{c-e}	2312^{b}	36^{ab}	3500^{b}	15^{f-i}
Chare	6	78^{f}	117^{f}	170^{i}	22^{d-f}	1893^{de}	27^{i}	2520^{ef}	93^{b}
Abebe	7	81^{e}	132^{d}	278^{b-e}	18^{hi}	1646^{f}	28^{hi}	1735^{k}	5^{j}
Alaela	7	91^{ab}	148^{ab}	300^{a}	18^{hi}	1767^{ef}	31^{e-g}	2208^{hi}	6^{ij}
Buwa	7	90^{ab}	147^{ab}	267^{de}	19^{g-i}	1800^{ef}	29^{gh}	1850^{jk}	32^{d}
Amsel	6	84^{cd}	139^{c}	262^{e-g}	25^{bc}	2030^{cd}	33^{c-e}	2700^{e}	16^{f-h}
Atish	7	83^{c-e}	133^{d}	250^{f-h}	18^{hi}	1683^{f}	29^{gh}	2350^{f-h}	16^{f-h}
Birle	6	82^{de}	128^{e}	288^{ab}	26^{b}	2448^{ab}	37^{a}	3750^{a}	8^{g-i}
Tewzale	6	84^{cd}	134^{d}	285^{a-c}	35^{a}	2616^{a}	34^{bc}	3260^{c}	40^{cd}
Kodon	7	85^{c}	141^{c}	266^{d-f}	19^{g-i}	2104^{c}	34^{e-g}	2410^{fh}	45^{c}
Daka	7	92^{a}	145^{b}	275^{b-e}	25^{bc}	2300^{b}	33^{cd}	3000^{d}	18^{f-g}
Merawi	7	90^{ab}	146^{ab}	245^{gh}	24^{b-d}	2091^{c}	32^{e-g}	2300^{gh}	21^{ef}
Minaba	7	89^{b}	138^{c}	270^{c-e}	12^{j}	1358^{j}	23^{j}	1300^{l}	7^{h-j}
Mitswa	7	91^{ab}	149^{a}	280^{b-d}	20^{f-h}	1770^{ef}	31^{e-g}	2000^{j}	30^{de}
GM	6.67	86.3	138.4	262.4	22	1966.9	31.4	2460	32
LSD (5%)	ns	1.42	1.01	9.56	1.3	106.7	1.4	150	5.8
CV (%)		1.01	1.6	2.2	3.6	3.2	2.7	3.6	11

ns= non-significant, GM= grand mean, LSD = least significant difference, CV = coefficient of variation, DE = days to emergence (days), DF = days to flowering (days), DM= days to maturity (days), PH= plant height (cm), PL= panicle length (cm), NSPP= number of seeds per panicle, TGW=thousand grain weight (g) GY= Grain yield (kg ha-1), SCPP = striga count per plot

indicates the fair level of scope for phenotypic selection. Similarly, moderate PVC and GVC in sorghum for plant height was reported by Gedifew and Tsige (2019). On the contrary, Fantaye and Hintsa (2017) observed low PVC and GCV for plant height, number of seeds per panicle and thousand grain weight in their study.

Low phenotypic and genotypic coefficient of variation values (<10%) were found for the traits viz., days to 50% flowering (5.0, 4.9) and days to physiological maturity (6.5, 6.4). Hence it can be concluded that direct phenotypic selection for these traits may not be rewarding. The result agreed with the findings of Gedifew and Tsige (2019) who found lower PVC and GVC for days to 50% flowering and days to physiological maturity in sorghum [16].

Heritability estimates in broad sense

The estimate of broad sense heritability for the traits studied is presented. All the traits were recorded high heritability ranged from 96.2% to 99.1%, indicating additive gene effects control the expression of the characters. Heritability is classified as low (<40%), medium (40-59%), moderate (60-79%) and high (≥80%). According to Singh (2001), high heritability of a trait (≥ 80%) provides selection for such traits could be fairly easy due to a close correspondence between the variety and the phenotype due to the relatively small contribution of the environment to the phenotype.

Based on this idea, the highest estimates of broad sense heritability were recorded for grain yield (99.1) followed by days to maturity (98.2), thousand grain weight (97.8), panicle length (97.8), number of seeds per panicle (96.7), plant height (96.6) and days to 50% flowering (96.2). This result is in agreement with the previous works who reported very high broad sense heritability for sorghum in Ethiopia by Kassahun et al. (2011) for days to flowering and days to maturity; Gedifew and Thige (2019) for days to flowering, plant height and days to maturity and Gobezayehu et al. (2019) for days to flowering, days to maturity, grain yield, thousand grain weight, panicle length. However, heritability alone provides no indication of the amount of genetic improvement [17].

Expected genetic advance for selection

High heritability along with high genetic advance as percent of mean is an important factor for predicting the resultant effect of selecting the best individuals. Jonhson et al. (1955) classified genetic advance as percent of mean (GAM) values < 10% is low, 10 to 20% is moderate and > 20% is high. Based on the above GAM in this study varies from low (9.95) in days to flowering to high (56.80) for grain yield. High heritability together with high GAM were observed for the traits, grain yield, panicle length, number of seeds per panicle, thousand grain weight and plant height. Similarly, Tamirat et al. (2021) and Habtamu and Habtamu (2022) reported high heritability coupled with high GAM for plant height, panicle length, thousand grain weight and grain yield in sorghum. This indicates that the traits are highly heritable (Table 3) [18].

Conclusion

The morphological characterization in this study revealed a significant genetic variability among sorghum landraces for days to 50% flowering, days to 90% maturity, plant height, panicle length, number of seeds per panicle, thousand grain weight, grain yield and reaction to striga infestation. Hence, there is a chance for selection for the majority of the traits in the genotypes.

Five sorghum landraces, namely Birle, Woitozira, Tewzale, Daka and Amsel were identified as superior genotypes compared to the check variety. The phenotypic coefficient of variation (PCV) had exceeded the genotypic coefficient of variation (GCV) for all the variables studied, suggesting certain degree of interaction with the environment.

The heritability estimates for all traits examined under this study were found to be high. High heritability coupled with high GAM were attained for grain yield, panicle length, number of seeds per panicle, thousand grain weight and plant height. In conclusion, genetic improvement through selection for these traits would be more rewarding. Therefore, the variability observed in this study could be given emphasis while planning a breeding strategy for further sorghum breeding program to enhanced grain yield.

Table 3: Mean squares of agronomic traits from analysis of variance, estimates of phenotypic and genotypic variances and coefficient of variations, heritability in broad sense, genetic advance and genetic advance as percent of mean.

Traits	MSg (df=14)	MSe (σ^2e) (df=28)	Mean	σ^2g	σ^2p	GCV%	PCV%	H^2%	GA	GAM%
DF	81.85**	0.72	86.3	18	18.7	4.9	5	96.2	8.6	9.95
DM	237.7**	1.47	138.4	78.7	80.2	6.4	6.5	98.2	18.1	13.1
PH	2813.3**	32.66	262.4	926.9	959.5	11.6	11.8	96.6	61.7	23.5
PL	83.05**	0.614	22	27.5	28.1	23.8	24.1	97.8	10.7	48.6
NSPP	356522**	4020	1966.9	1E+05	121521	17.4	17.7	96.7	695.4	35.4
TGW	83.05**	0.614	31.4	27.5	28.1	16.7	16.9	97.8	10.7	34.1
GY	1390834**	4282	2460	5E+05	466466	27.6	27.8	99.1	1396.1	56.8

*, ** = significant at P≤ 0.05 and P≤ 0.01, respectively.
Where: df= degree of freedom, DF= days to flowering, DM = days to maturity, PH = plant height, PL = panicle length, NSPP = number of seeds per panicle, GY = grain yield, TGW = thousand grain weight; MSg = mean square of genotypes, MSe = mean square of error (environmental variance, δ2e), σ2g = genotypic variance, σ2p = phenotypic variance, PCV = phenotypic coefficient of variance (%), GCV = genotypic coefficient of variance (%), H2 = broad sense heritability (%), GA = Genetic advance and GAM = genetic advance as percent of mean (%).

Authors Contribution

FB designed the study, collect & analyzed the data and drafted the manuscript, HM and KF contributed to collect data. Authors are check and approved the final manuscript

Competing Interest

The authors declare no competing interest.

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