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Genetic Variability Studies in Dry Lowland Sorghum Landraces of Abergelle, Northern Ethiopia

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ABSTRACT

Background and Objective: Even though sorghum is the dominant cereal crop in Tigray region of Ethiopia, a limited research has been undertaken on existing sorghum landrace variability. Thus, this study aimed to assess the presence and degree of variability among fifteen sorghum landraces for desired agro-morphological traits at Abergelle Agricultural Research Center during the 2020 cropping season. **Materials and Methods:** The field experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. Data were collected and analyzed for a variance in days to emergence, days to flowering, maturity, plant height, panicle length, number of seeds per panicle, thousand grain weight, grain yield and striga counts at sorghum harvesting under random stress conditions. **Results:** Based on mean performance the genotypes Birle (3750 kg/ha), Woitozira (3500 kg/ha), Tewzale (3260 kg/ha), Daka (3000 kg/ha) and Amsel (2700 kg/ha) were found to be superior over check variety Chare. The phenotypic coefficient of variation (PCV) exceeded the genotypic coefficient of variation (GCV) for all the variables studied, suggesting a certain degree of interaction with the environment. Moreover, high heritability coupled with high genetic advance as percent of the 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. Therefore, improvement of these traits could be done through selection. **Conclusion:** The high yield performance of sorghum landraces screened in this study could be exploited as a source of breeding materials for further sorghum improvement to enhance grain yield.

KEYWORDS

Agro-morphological traits, coefficient of variation, genetic advance, grain yield, sorghum

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 ha) and number of farmers (4.3 million) producing the commodity. Oromia and Amhara regions are the highest sorghum producers (76%) followed by Tigray region, ranked third next to Oromia and Amhara in terms

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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 cereal crops might fail and food insecurity is rampant[1].

Sorghum is a staple crop for more than 500 million people in 30 Sub-Saharan African and Asian countries and is essential to the food security of over 300 million people in Africa[2]. There are numerous varieties of sorghum cultivated globally, each adapted to different environmental conditions and intended uses. These varieties can be broadly categorized into grain sorghum, sweet sorghum and forage sorghum. It is utilized in various ways. Sorghum flour (fermented or unfermented) is used for human food such as bread, porridge, couscous and snacks and beverages. The grain and fresh or dry biomass have diverse uses and good sources for sugar, syrup and molasses industries[3]. It is also the second most important crop for “injera” quality next to tef in Ethiopia. In addition, sorghum stalks and leaves are an important source of dry season feed for livestock, a source of energy for cooking their daily foods, for the construction of houses and fences and as fuel wood.

Ethiopia is believed to be the center of origin and diversity for sorghum[4], which indicates the availability of extremely rich genetic diversity in sorghum landraces[5-7]. Ethiopian farmers grow with over 95% of the area allocated for sorghum production covered by landraces[8]. As a result, the Ethiopian sorghum landrace collections have been used as the main source of several genes for important agronomic traits[9] in many national and international sorghum breeding programs.

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 and diversity of sorghum in Ethiopia, inadequate research attention was given to locally available sorghum landraces in the 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 landraces that contribute to grain yield.

MATERIALS AND METHODS

Description of the study area: A field experiment was conducted at Abergelle Agricultural Research Center on a station in the Central Zone of the Tigray Region, Ethiopia during the 2020 cropping season. The research station is situated at a Latitude of 13°14'06"N and a Longitude of 38°58'50"E at an elevation of 1560 m above sea level (m.a.s.l.) in Abergelle District. The area lies in a hot warm sub-moist lowland (SML-4b) agro-ecology classification with a 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 range from 300-600 mm and 18-41°C, respectively, which is characterized by uneven erratic distribution and variable results in strong variation in crop yields. The soil texture of the research site is sandy clay with neutral (7.12) pH and high (22.6%) CEC, low (0.08) nitrogen content and high available phosphorus.

Experimental materials, design and field management: The experimental plant materials comprised 15 sorghum landraces including check variety is presented in Table 1. The landraces were collected from farmers' fields at the maturity of sorghum from dry lowland areas of Abergelle, Temben Provinces 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 5 m length with a row-to-row distance of 75 cm and plant-to-plant distance of 20 cm. The three middle rows were harvested and two border rows were left to exclude border effect. The gross area of the experimental plot and the harvestable area had a size of 18.75 m^2 (3.75×5 m) and 11.25 m^2 (2.25×5 m), respectively, separated by a distance of 1.5 m between replications. Each plot was fertilized uniformly with NPS fertilizer applied at

Table 1: Descriptions of the plant materials used in the study

Local name	Collection year	Collection area	Status	Maturity group	Days to flowering	Plant height group	Races	Seed color
Chibal	2019	Abergelle	Landrace	Medium	89	Tall	Caudatum	Red
Woitozira	2019	Abergelle	Landrace	Medium	84	Tall	Dura	White
Chare	Check variety	DBARC	Improved	Early	78	Short	Bicolor	White
Abebe	2019	Abergelle	Landrace	Medium	81	Tall	Dura	Red
Alaela	2019	Abergelle	Landrace	Medium	91	Tall	Dura	Yellow
Buwa	2019	Abergelle	Landrace	Medium	90	Tall	Caudatum	Yellow
Amsel	2019	Abergelle	Landrace	Medium	84	Tall	Dura	White
Atish	2019	Abergelle	Landrace	Medium	83	Tall	Caudatum	White
Birle	2019	Abergelle	Landrace	Medium	82	Tall	Dura	White+scattered red
Tewzale	2019	Abergelle	Landrace	Medium	84	Tall	Caudatum	Red
Kodon	2019	Abergelle	Landrace	Medium	85	Tall	Dura	Chalky
Daka	2019	Abergelle	Landrace	Medium	92	Tall	Dura	White
Merawi	2019	Abergelle	Landrace	Medium	90	Tall	Caudatum	Chalky
Minaba	2019	Abergelle	Landrace	Medium	89	Tall	Dura	White
Mitswa	2019	Abergelle	Landrace	Medium	91	Tall	Caudatum	White

DBARC: Debre Birhan Agricultural Research Center, Maturity group: Early <120 days, Medium: 121-150 days, Late: >151 days (local area classification), Height group: <150 cm = short, 151-200 cm = medium, >201 cm = tall (local area classification)

planting (19 kg/ha N, 38 kg/ha P_2O_5 and 7 kg/ha S), with an additional 23 kg/ha of nitrogen in the form of Urea side-dressed when the crop reached knee height. All other agronomic practices were applied as per the recommendations for sorghum in the study area.

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 descriptor list[10]. For single plant-based traits, the mean value of five plants was tagged randomly before the time of data collection.

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 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 when 90% of the plant matured on which seeds on the lower part of the panicle formed a black layer
- **Grain yield (kg/ha):** 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 for analysis
- **Thousand grain weight:** The weight of 1000 randomly sampled grains from each plot was measured in grams 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

Statistical analysis: Data (agro-morphological and Sriga counts) were subjected to Analysis of Variance (ANOVA) following a procedure appropriate to RCBD[11]. Mean separation was done using Fisher's least significant difference (LSD) test at 5% probability level. Genotypic variances and coefficients of variations as suggested by Burton and Devane[12], components of variance (δ^2p, δ^2e, δ^2g) for the estimation of coefficients of variation (PCV, GCV) as described by Singh and Chaundry[13] and broad sense heritability (H^2) and genetic advance as percent of mean (GAM) were calculated by the formula given[14,15].

RESULTS AND DISCUSSION

Analysis of variance: The results of analysis of variance for different traits of sorghum landraces were presented in Table 2. In the table, the genotypes revealed highly significant ($p<0.01$) differences for all the traits studied except days to emergence, indicating the existence of variation among the sorghum landraces for the studied traits. In agreement with this finding, many authors[16-21] have reported the existence of genetic variability for days to flowering, days to maturity, plant height, panicle length and thousand grain weight in Ethiopian sorghum landraces.

Mean performances of sorghum genotypes: There was a genetic variation among landraces for days to 50% 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 the early maturing variety with 117 days followed by the medium maturing (128 days) landrace Birle where Mitswa was late and 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 the tallest panicle length was Tewzale at 35 cm, while the shortest was Minaba at 12 cm and the difference with the other landraces was significant.

The result of the present study also revealed significant differences in a number of seeds per panicle (NSPP) ranging from 1358 to 2616 with a 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 31.4 g. The genotype Birle scored the highest TGW (37 g) followed by Woitozira and Tewzale with TGW (36, 34), respectively, while Minaba recorded the smallest TGW (25 g).

The average mean grain yield of landraces was 2460 kg/ha. Birle (3750 kg/ha), Woitozira (3500 kg/ha), Tewzale (3260 kg/ha), Daka (3000 kg/ha) and Amsel (2700 kg/ha) were found the best sorghum landraces that yielded above average and gave better grain yield than the check variety Chare (2520 kg/ha) while the lowest yield was attained from Minaba (1300 kg/ha). 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, Egziabher *et al*.[21] reported that grain yield increased as the yield attributed traits, such as panicle length and panicle weight increased.

Table 2: Analysis of variance for different traits of sorghum landraces at Abergelle during the 2020 main cropping season

	Traits								
Landraces	DE	DF	DM	PH	PL	NSPP	TGW	GY	SCPP
Chibal	6.00	89^{b}	145^{b}	235^{h}	21^{e-g}	1687^{f}	32^{e-g}	2187^{ij}	120^{a}
Woitozira	7.00	84^{cd}	134^{d}	265^{d-f}	23^{c-e}	2312^{b}	36^{ab}	3500^{b}	15^{f-i}
Chare	6.00	78^{f}	117^{f}	170^{i}	22^{d-f}	1893^{de}	27^{i}	2520^{ef}	93^{b}
Abebe	7.00	81^{e}	132^{d}	278^{b-e}	18^{hi}	1646^{f}	28^{hi}	1735^{k}	5^{j}
Alaela	7.00	91^{ab}	148^{ab}	300^{a}	18^{hi}	1767^{ef}	31^{e-g}	2208^{hi}	6^{ij}
Buwa	7.00	90^{ab}	147^{ab}	267^{de}	19^{g-i}	1800^{ef}	29^{gh}	1850^{jk}	32^{d}
Amsel	6.00	84^{cd}	139^{c}	262^{e-g}	25^{bc}	2030^{cd}	33^{c-e}	2700^{e}	16^{f-h}
Atish	7.00	83^{c-e}	133^{d}	250^{f-h}	18^{hi}	1683^{f}	29^{gh}	2350^{f-h}	16^{f-h}
Birle	6.00	82^{de}	128^{e}	288^{ab}	26^{b}	2448^{ab}	37^{a}	3750^{a}	8^{g-i}
Tewzale	6.00	84^{cd}	134^{d}	285^{a-c}	35^{a}	2616^{a}	34^{bc}	3260^{c}	40^{cd}
Kodon	7.00	85^{c}	141^{c}	266^{d-f}	19^{g-i}	2104^{c}	34^{e-g}	2410^{fh}	45^{c}
Daka	7.00	92^{a}	145^{b}	275^{b-e}	25^{bc}	2300^{b}	33^{cd}	3000^{d}	18^{f-g}
Merawi	7.00	90^{ab}	146^{ab}	245^{gh}	24^{b-d}	2091^{c}	32^{e-g}	2300^{gh}	21^{ef}
Minaba	7.00	89^{b}	138^{c}	270^{c-e}	12^{j}	1358^{j}	23^{j}	1300^{l}	7^{h-j}
Mitswa	7.00	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 (%)	ns	1.01	1.6	2.2	3.6	3.2	2.7	3.6	11

ns: Non-significant, DE: Days to emergence, DF: Days to flowering, DM: Days to maturity, PH: Plant height (cm), PL: Panicle length (cm), NSPP: Number of seeds per panicle, TGW: Thousand grain weight (g), GY: Grain yield (kg/ha), SCPP: Striga count per plot, GM: Grand mean, LSD: Least significant difference and CV: Coefficient of variation in percent and values with the same letters in a column are not significantly different at $p \leq 0.05$.

Table 3: Mean squares of genetic variability components, mean, heritability and genetic advance (GA as percentage of mean) for the quantitative traits investigated

Traits	MSg	MSe (σ^2e)	Mean	σ^2g	σ^2p	GCV	PCV	H^2 (%)	GA	GAM
DF	81.85**	0.72	86.3	18.0	18.7	4.9	5.0	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	13.10
PH	2813.3**	32.66	262.4	926.9	959.5	11.6	11.8	96.6	61.7	23.50
PL	83.05**	0.614	22	27.5	28.1	23.8	24.1	97.8	10.7	48.60
NSPP	356522**	4020	1966.9	117501	121520.7	17.4	17.7	96.7	695.4	35.40
TGW	83.05**	0.614	31.4	27.5	28.1	16.7	16.9	97.8	10.7	34.10
GY	1390834**	4282	2460	462184.0	466466.0	27.6	27.8	99.1	1396.1	56.80

*,**Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively, 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, δ^2e), σ^2g: Genotypic variance, σ^2p: Phenotypic variance, PCV: Phenotypic coefficient of variance (%), GCV: Genotypic coefficient of variance (%), H^2: Broad sense heritability (%), GA: Genetic advance and GAM: Genetic advance as percent of mean (%)

Besides, the analysis of variance result exhibited a significant ($p \leq 0.01$) difference among landraces in reaction to Striga infestation (Table 2). The smallest number of Striga counts per plot (5, 6, 7, 8) at the harvesting of sorghum were recorded from Abebe, Alaela, Minaba and Birle, respectively, while the highest number of Striga counts per plot (120) was recorded from the sorghum landrace Chibal (Table 2). This result concurred with the finding of Abate *et al.*[22] who reported variability in sorghum responses to striga infestation.

Variability estimates of quantitative traits: The genetic variability components viz δ^2p, δ^2e, δ^2g, GCV (%), PCV (%), H^2 (%) and GAM for the traits investigated were presented in Table 3. The analysis of variance revealed that the mean squares for the genotypes were highly significant ($p<0.01$) for all traits studied, indicating the presence of adequate variability among sorghum landraces.

Phenotypic and genotypic coefficient of variation (PVC and GCV) values are categorized as low (<10%), moderate (10-20%) and high (>20%). Accordingly, 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 the presence of a high amount of variability and thus the phenotypic selection of these traits would be rewarding. In harmony with the findings of Amare *et al.*[23] 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 indicates the fair level of scope for phenotypic selection. Similarly, moderate PVC and GVC in sorghum for plant height were reported by Gedifew and Tsige[17]. On the contrary, Belay and Meresa[24] 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[17] who found lower PVC and GVC for days to 50% flowering and days to physiological maturity in sorghum.

Heritability estimates in broad sense: Heritability is classified as low (<40%), medium (40-59%), moderate (60-79%) and high (≥80%)[25]. 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 Amare *et al.*[23] for days to flowering and days to maturity; Gedifew and Tsige[17] for days to flowering, plant height and days to maturity and Gebremedhn and Mekbib[25] for head weight, panicle yield, thousand grain weight and plant height. However, heritability alone provides no indication of the amount of genetic improvement.

Expected genetic advance for selection: High heritability along with high genetic advance as a percent of the mean is an important factor for predicting the resultant effect of selecting the best individuals. Johnson *et al.*[14] classified genetic advance as a percent of the 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 (Table 3). 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, Bejiga *et al.*[18] and Alemu and Demelash[19] reported high heritability coupled with high genetic advance as a percent of the mean (GAM) for plant height, panicle length, thousand grain weight and grain yield in sorghum. This indicates that the traits are highly heritable.

CONCLUSION

The morphological characterization in this study revealed a significant genetic variability among sorghum landraces for the traits studied. The sorghum genotypes, namely Birle, Woitozira, Tewzale, Daka and Amsel were identified as superior genotypes compared to the check variety chare. The heritability estimates for all traits examined in 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. Overall, genetic improvement through selection for these traits would be more rewarding. Therefore, the variability observed in this study could be emphasized while planning a breeding strategy for further sorghum breeding programs to enhance grain yield.

SIGNIFICANCE STATEMENT

This study discovers the tested sorghum landraces' genetic variability, heritability and genetic advance. The relative high yield performance of sorghum landraces screened in this study could be exploited as a source of breeding materials for further sorghum improvement programs. It also indicates yield attribute traits of the sorghum collections considered and further selection of these traits could improve the entries. Thus, direct selection of these traits and incorporation of selected individuals in breeding programs would improve the grain yield of sorghum.

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