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Performance Evaluation of Finger Millet (*Eluesine coracana* L. Gaertn) Varieties for Grain Yield in Buno Bedele, South West Oromia, Ethiopia

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Abstract

Finger millet is adaptable to adverse agro-ecological conditions with low input, tolerant to moisture stress and plays a significant role both as food grain and animal feed in areas where production of other cereals are reduced by marginal environments. The national and regional research centers recommended considerable numbers of varieties to varied agro- ecologies to increase the productivity of finger millet. Hence, it is necessary to evaluate varieties for stability of yield at varying environments. To this end, this study was conducted with the objective of identifying high yielding, biotic and abiotic stresses resistance or tolerance varieties adaptable to Buno Bedele Zone of Western Oromia. A total of nine finger millet varieties including local check were evaluated in RCBD. The combined data analysis for grain yield was very highly significant across locations and years. AMMI analysis showed that environments, varieties and their interaction effects were significantly different. The stability and high yielding ability of the varieties have been graphically depicted by the AMMI bi-plot. The variation for seed yield among the varieties for each variety was significant at different environments. Varieties such as Boneya and Gute were widely adapted to high yielding environments. In GGE bi-plot analysis; IPCA1 and IPCA2 explained 48.02% and 34.34% of variation, respectively, of finger millet variety by environment interaction and made a total of 82.36% of variation. Therefore, Boneya (34.39 qtha^{-1}) and Gute (33.44 qt ha^{-1}) were identified as most stable and thus recommended for production in the study area and similar agro-ecologies.

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AMMI, Finger millet varieties, GGE bi-plot, GEI, Stability.

Introduction

Finger millet (*Eluesine coracana* L. Gaertn) is belongs to family Poaceae. The cultivated *Eleusine coracana* is an allotetraploid with chromosome number 2n=4x=36, the most important among small millets grown for food and fodder. It is the fourth most important millet covering 10% of the global millet area in more than 25 countries of Asia and Africa (Saritha, 2015). It is a small grain crop, which is indigenous to East Africa, especially Uganda and Ethiopian highlands and introduced in to India approximately 400years ago (Haore *et al.,* 2007). It is also believed to be adapted to the arid and semi-arid regions of the world and is highly tolerant to pests, diseases and drought (Gowda *et al.,* 2015). Finger millet growing countries: India, Uganda, Tanzania, Kenya, Ethiopia, Rwanda, Zaire, Zambia, Zimbabwe, Eritrea, Somalia, China, and Myanmar are some of them (Dagnachew, 2012). It is the second most widely grown millets on the continent of Africa and is an important crop grown in low input farming systems by resource poor farmers in eastern Africa and Asia (Damar *et al.*, 2016).

Finger millet grain can be stored for several years under local storage conditions without sustaining significant damage by storage pests (Asfaw *et al.*, 2011). Finger millet straw is used for livestock feed in many countries, however, it is mainly grown for food (Upadhyaya *et al.*, 2006) and also for brewing of gluten free beverages (Shayo *et al.*, 2001 and *Bano et al.*, 2015). It is potentially a climate-resilient and nutritious crop with highly nutritive and antioxidant properties (Kumar *et al.*, 2017) and very importantly, grain rich in calcium, fiber, iron and has excellent malting qualities (Chandrashekar, 2010). In Ethiopia, it is an important staple food crop widely grown and traditionally it is used for making bread 'injera' mixed with tef, porridge, local beer 'tella' and a powerful distilled spirit 'areke' and a number of other uses (Andualem, 2008).

African countries contributed 61 percent of area under millets and 47 percent of production followed by India (31.2 percent of area and 42.53 percent of production). Among African countries Ethiopia contributed 2.1 percent of area and 4.8 percent of production of millets. In Ethiopia, finger millet is produced on about 3.60% (456,057.32 ha) of land and produced 1,030,823.153 tons in 2010 'meher' season (CSA, 2021). The share of national finger millet production was from Oromia that was about 93,831.88ha area of land (219,537.397 ton) with national average grain yield is far below the potential 2.1 tones (CSA, 2021). Among factors that contributed to the fluctuation of finger millet yield were low in yielding due to shortage of high yielding cultivars, distribution of limited number of improved varieties, moisture stress, lodging effect, diseases, low fertility and poor crop management practices. Strengthen the seed production and delivery systems for improved varieties also the most bottleneck of the crop in the small scale farmers.

However, the performance evaluations of the finger millet varieties before release were conducted in limited agro ecologies. Kebede *et al.*, (2019) studied some genotypes in western Oromia (Bako and Gute) and Geleta *et al.*, (2019) only eight varieties were evaluated in western Oromia (Haro-sabu), but no research was conducted in eastern Ethiopia and most varieties that were released by Melkassa and Adet agricultural research center not evaluated in western Ethiopia. Hence, the evaluation of finger millet varieties for stability of performance under varying environmental conditions for yield is becoming an important aspect. Thus, this research was conducted to achieve the following objective. To evaluate and recommend better adapted finger millet varieties for yield and yield components and diseases tolerant for the study areas and other similar agro-ecologies

Materials and Methods

Description of the study areas

The experiment was conducted in Gechi, Dabo Hana and Bedele districts in Buno Bedele Zone on different farmers' field during 2021-2022 main cropping seasons.

Gechi District

Gechi is one of the districts in Buno Bedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Didessa, on the west by Didessa River, on the north by Bedele, and on the east by Jimma Zone. The administrative center of this district is Gechi. The district is located 465 km away from the capital city of the country and 18 km away from Bedele Town. The district is located at an average elevation 1277-2467m.a.s.l and located at 8°16'60''N latitude and 36°34'00''E longitude. The annual rainfall ranges from 1500-2100mm. The economy of the area is based on coffee production system in which the dominant crops are maize, tef, sorghum and wheat and also horticultural crops.

Dabo Hana District

Dabo Hana is one of the districts in Buno Bedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Bedele, on the west by Dega and Mako, on the north by Chewaka and Lekadulecha, on south west by Chora, on the east and north east by Jima Arjo. The administrative center of this district is Dabo Hana. The district is located 521 km away from the capital city of the country and 38 km away from Bedele Town. The district is located at an average elevation of 1190-2323 masl and located at 8°30' 21" to 8°43' 29" N latitude and 36°5'27" to 36°26' 19"E longitude. It is generally characterized by warm climate with mean annual maximum temperature of 28°C and minimum temperature of 11°C. The annual rainfall ranges from 900-2200mm. The soil of the area is characterized as Nitisol, Acrisol, Lithosol, Cambisol and Vertiso.

Bedele District

Bedele district, which is located in BunoBedele zone of Oromia Regional National State, Southwestern Ethiopia. The district is located between 8°14'30"N to 8°37'53"N and 36°13'17"E to 36°35'05"E is about 483km road distance south-west of Finfine. It is covers 74497.425 hectares of which 47,986, 9477, and 10,120 hectares are cultivated, forest and grazing land, respectively.

The area is covered with variety of crops and species of natural vegetation. The dominant crops in the area are maize, tef, sorghum, finger millet and haricot bean. The major land use types are cultivated land/cropland, forestland and grazing land (Bedele development agricultural office, 2019).

Experimental Materials and Design

Nine (9) finger millet varieties collected from Bako Agricultural Research Centers including local check were evaluated for their overall performance in the study areas. These materials were randomly assigned to the experimental block and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The spacing between blocks and plots was 1.5m and 0.5m, respectively. The gross size of each plot was 6m^2 (3m x 2m) having five rows with a row-to-row spacing of 40cm.The total area of the experimental field was 279m^2 (31m x 9m). Planting was done by drilling seeds in rows with a seed rate of 15kg ha^{-1}. NPS fertilizer was applied at the rate of 100kg ha^{-1} at the time of planting; and Urea was also applied at vegetative stage at the rate of 100 kg ha^{-1}.

Data collected

Days to 50% heading (DH)

Number of days from emergence to the time when half of the plants in the plot bloomed.

Days to maturity (DM)

Number of days from planting to the stage when of plants in a plot has at least 90% of dried heads.

Plant Height (PH) (cm)

It was recorded by measuring the height of plants from ground level to the tip of inflorescence (ear), at dough stage.

Finger Length (FL) (cm)

Finger length was recorded from the base of the finger to the tip of the finger at each five randomly taken plants of main tillers, at dough stage.

Number of Fingers per head (NFPH)

The number of fingers per head was recorded from five randomly taken plants at harvest.

Grain Yield (SYD) (kg ha^{-1})

Grain yield was determined by harvesting all plants from all rows of each plot and grain yield was weighed by sensitive balance in kilo gram and approximately adjusted to 12.5% moisture content by drying in the sun.

Blast Disease (neck blast and finger blast)

Blast Disease (neck blast and finger blast) were recorded using (1-9) scoring scale 1 as immune or highly resistance (No visible disease symptom), 2= resistant, 3 = moderately resistant, 4= moderately susceptible 5 = susceptible and 6-9=highly susceptible. The disease was scored for neck and finger blast at dough stage from each tested locations (Kiran *et al.*, 2013).

Data Analyses

Genstat 18th edition software was used to analyze all the collected data from individual farmers and the combined data over locations. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

Results and Discussion

The pooled analysis of variance for grain yield revealed that highly significant variation for locations, genotypes and genotypes by location interaction at $P<0.01\%$ (Table 2). This result is supported by the earlier works of Likewise, Kebede *et al.*, (2019) and Geleta *et al.*, (2019) on finger millet, reported large variation in grain yield performance among different tested genotypes across environments. The significant of GEI for grain yield indicates the genotypes responded differently to the tested environments. Of the total SS variation for grain yield, 29.71% was accounted by genotypes followed by genotypes by environment interactions (5.77%) and locations (2.60%). From this it is concluded that the genotypes were more stable across locations for the variation obtained in grain yield at each tested locations.

Mean performance of grain yield varieties at each environment

The mean performance of variety for grain yield at each environment and over environments is presented in (Table 3). The mean grain yield of locations averaged over varieties ranged from 24.58 qtha^{-1} to 34.39qtha^{-1}. This indicating the high environmental variations and differential response of varieties to the variable environments. Similar results were reported by Dagnachew *et al.*, (2014) on Triticale and Kebede *et al.*, (2019) on finger millet.

The average mean grain yield of location was highest at Bedele (39.89 qt followed by Dabo Hana (38.76 kg ha^{-1}) without significant difference among them. The mean yield reductions were exhibited might be due to variable environments during growth stage and grain filling stag. Similar result was reported by Sonia *et al.*, (2013) the significant negative effect of stresses on grain yield potential if it happens at any stage of crop growth.

Since yield is the final result from the interaction of various plant characters and the environmental factors during the life span of the plant development, the ranking of genotypes based on grain yield can be considered as a reliable measure for genotypic performance.

Accordingly, Variety Wama was scored the highest grain yield (39.89.1qtha^{-1}) at Bedele followed by Boneya (38.66qtha^{-1}). At Dabo Hana, Boneya and Wama were the two best yielder varieties with mean grain yield of 38.76 qtha^{-1}and 34.02 qtha^{-1} respectively. At Gechi, Boneya (22.72 qtha^{-1}) was scored superior mean yield followed by variety Gudetuwith21.39 kgha^{-1}.

Yield-related traits

Differences among the genotypes were significant for agronomic characters (Table 4). A local variety included in this study was the intermediate to days to heading (104.20 days). Boneya and Gudetu were almost the earliest to days to maturity whereas Local variety (Gimire) and Gute were the late maturing varieties.

In terms of plant height Gudetu and Addis-01 were the shorter whereas Gute and Bareda were comparatively the taller varieties. The longest finger length was recorded from Urji and Bareda while the shortest finger length was recorded from Gudetu and Kumsa. The mean value finger blast infection of varieties across locations ranged from 5r to 15mr.This indicate, varieties were felled in the range of highly resistant to moderately resistant to disease infection (Table 4).

Stability Analysis

AMMI Analysis for Grain Yield

The AMMI analysis of variance of grain yield showed that environment, genotype and genotype by environment interaction were highly significant (P<0.001) (Table 5). The factors explained showed that finger millet genotypes grain yield was affected by environment (42.57%), genotype (9.53%) and GEI (14.03%).

The results revealed that there were significant differences among the tested genotypes for grain yield, which suggested that the genotypes differed considerably with respect to yield performance. These results illustrated the presence of genetic variability among varieties and the location was diverse.

The highly significant effect of location on yield was reported by Wossen (2019) on finger millet, Abebaw *et al.*, (2020) on cold tolerant green super rice genotypes, Almeida *et al.*, (2014) on sorghum, Fentie *et al.*, (2013) and Asfaw (2011) on finger millet, Shrestha *et al.*, (2012) on upland rice. Moreover, the significant G x E interaction indicated the differential response of genotypes grown across environments was described by Gebeyaw (2019) on faba bean, and Zelalem (2011) on bread wheat.

A large yield variation explained by GEI and environment indicated that genotypes had various performances across environments and the environments were diverse, with large difference among environmental means causing most of the variation in grain yield. In line with this, many researchers reported the dominance of environmental effect in the combined analysis of grain yield (Kebede *et al.*, 2018; Tariku, 2018; Dolinassou *et al.*, 2016 and Mohammed *et al.*, 2011).

The significant effect of genotype by environment interaction (GEI) indicated that grain yield of genotypes varied across tested environments or the response of genotypes at different environments was varied. The AMMI analysis of variance (multiplicative effect) was further exploited by decomposition principal components analysis. The multiplicative variance of the genotypes sum of squares due to GEI was partitioned into IPCAs. IPCA-I score explained 48.02% and IPCA-II 34.34% of the variability (Table 5). Therefore, as indicated by the F-test, inclusion of the first two interactions PCA axes (IPCA- I & IPCA- II) that captured 82.36 % of total portion of GEI variance was recommended in the model.

The four best genotypes selected by AMMI model

The four best varieties selected by the AMMI model in different environments are presented in (Table 6). The first highest yielder variety (Boneya) selected among the four best AMMI selection in five environments (D/Hana 2021, D/Hana-2021, Gechi-2021 and Bedele-2021) favorable.

The selection of genotype in respective environments is an indication of the best adaptation of the genotypes at those particular environments. The selection of genotype in respective environments is an indication of the best adaptation of genotypes in relation to the environments. Better selected in most environments as higher share indicated it had best adaptation. The other genotypes that were selected did not show a distinct pattern of adaptation and more specific adapted either higher or lower yielding environments (Table 6).

GGE Bi-plot for Evaluation of Genotypes and Environments

The residual mean square from AMMI model for grain yield was significant (Table 5) which suggested that the importance of constructing AMMI biplot is very low (Yayis *et al.*, 2014 and Tariku, 2018).

Hence, it is necessary to construct GGE biplot for visual observation in order to understand which varieties best performed in which environment, or which varieties were stable and unstable as well as to visualize the discriminating ability and representativeness of the environments. GGE bi-plot analysis is a multivariate analytical technique that graphically displays a two way table and allows visualizing the relation among genotypes, environments and their interactions. The “which-won-where“ or polygon view of the GGE bi-plot is an effective visual tool in mega environment analysis. The perpendicular lines to the polygon sides divide the biplot into sectors. If environments fall into different sectors, this suggests that different genotype won in different sector and thus genotype x environment interaction or crossover pattern exist. A polygon view of GGE biplot was formed by connecting the vertex genotypes with straight lines and the rest of the genotypes were placed within the polygon.

Table.1 Description of Finger millet varieties used for the experiment

Variety Name	Year of Release	Altitude (masl)	Releasing center	Yield Potential (qt/ha)		Seed color
				Research	Farmers	
Addis-01	2015	1400-2200	BARC/OARI	26-42	25-31	Brown
Bareda	2009	1200-1900	BARC/OARI	20-28	18-25	Brown
Boneya	2002	1200-1900	BARC/OARI	25-34	20-24	Brown
Gudetu	2014	1400-1900	BARC/OARI	21-23	20-21	Brown
Gute	2009	1200-1900	BARC/OARI	20-35	20-32	Brown
Kumsa	2019	1500-2200	BARC/OARI	25-32	22-29	Brown
Urji	2016	1600-2300	BARC/OARI	18-27	21-26	White
Wama	2007	1400-1900	BARC/OARI	17-35	16-30	Brown
Local	-	-	Farmers	-	-	Brown

BARC= Bako Agricultural Research Center, OARI= Oromia Agricultural Research Institute.

Table.2 Combined analysis of variance for finger millet varieties tested at three locations for two consecutive years

Source of variation	Degree of freedom	Sum of squares	Mean of squares	% Explained of TSS
Replication	2	290.70	145.35*	
Year (Y)	1	7.71	7.71*	
Locations (L)	2	95.79	47.89**	2.60
Genotypes (G)	8	1095.74	136.97**	29.71
Y*G	8	118.96	14.87*	
L*G	16	212.93	13.31**	5.77
Error	43	1866.43	43.41	
Total	80	3688.27		

Table.3 Combined mean grain yield (qt/ha) of Finger millet varieties tested at Bedele, D/Hana and Gechi districts for two years (2021/22-2022/23)

Sr. No	Varieties	Bedele			Gechi	D/Hana			Over all combined
		1st Year	2nd Year	Combined	1st Year	1st Year	2nd Year	Combined	
1	Addis 01	28.08 bc	36.14 abc	30.77 ab	18.06 abc	32.17 abc	21.00 c	23.17 c	25.99 c
2	Bareda	23.33 c	34.28 abc	26.98 b	10.94 d	26.50 bc	35.64 ab	27.14 bc	24.58 c
3	Boneya	44.08 a	27.81 c	38.66 a	22.72 a	39.58 a	41.78 a	38.76 a	34.39 a
4	Gudetu	37.11 abc	37.83 abc	37.35 ab	21.39 ab	30.86 abc	28.25 abc	27.36 bc	28.93 abc
5	Gute	32.50 abc	43.33 a	36.11 ab	17.00 bc	37.92 a	37.03 ab	33.84 ab	33.44 ab
6	Kumsa	34.72 abc	31.39 bc	33.61 ab	17.61 abc	25.42 c	28.42 abc	27.42 bc	25.58 c
7	Urji	31.92 abc	35.33 abc	33.06 ab	14.22 cd	35.78 ab	27.31 bc	31.03 abc	29.25 abc
8	Wama	39.08 ab	41.50 ab	39.89 a	17.11 bc	35.89 ab	33.17 abc	34.02 ab	33.00 ab
9	Local	31.14 abc	34.39 abc	32.22 ab	15.78 cd	30.00 abc	29.33 abc	27.31 bc	26.78 bc
GM		33.55	35.78	34.29	17.20	32.68	31.32	30.01	29.10
LSD (0.05)		14.40	11.40	10.45	5.21	10.09	13.82	9.51	6.78
CV%		29.90	18.40	32.40	17.50	26.50	25.50	33.7	35.40
P-value		*	*	*	**	*	*	*	**

GM= grand mean, LSD=least significant difference, CV= coefficient of variation, *= significant, **= highly significant.

Table.4 Combined mean yield related traits and diseases data of Finger millet varieties at Gechi, D/Hana and Bedele districts

Sr. No	Varieties	DF (days)	DM (days)	PH (cm)	FL (cm)	NFPP (No)	HB (1-5)
1	Addis 01	97.80[b]	159.4[b]	86.47[bc]	7.22[c]	7.02[bcd]	10r
2	Bareda	102.73[a]	158.8[b]	107.04[a]	10.78[a]	7.31[bc]	5r
3	Boneya	92.00[c]	157.2[b]	97.16[ab]	7.29[c]	7.51[b]	5r
4	Gudetu	92.67[c]	157.4[b]	83.38[c]	6.31[c]	7.29[bc]	5r
5	Gute	95.87[bc]	161.6[ab]	108.16[a]	9.20[b]	5.91[e]	5r
6	Kumsa	99.60[ab]	161.0[ab]	87.91[bc]	6.80[c]	6.24[de]	10r
7	Urji	96.07[bc]	158.0[b]	102.47[a]	11.07[a]	9.00[a]	15mr
8	Wama	95.00[bc]	158.6[b]	105.49[a]	8.60[b]	6.38[cde]	5r
9	Local	104.20[a]	165.6[a]	103.53[a]	6.89[c]	7.07[bcd]	15mr
GM		97.33	159.73	97.96	8.24	7.08	
LSD (0.05)		4.77	5.49	13.15	1.17	1.00	
CV%		6.8	4.8	18.6	19.6	19.6	
P-value		*	*	*	**	**	

DF= days to flowering, DM= days to maturity, PH= plant height, FL= Finger length, NFPP= Number of fingers per plant, HB= Head blast, GM= grand mean, LSD=least significant difference, CV= coefficient of variation, *= significant, **= highly significant.

Table.5 Analysis of Variance of AMMI model for grain yield of finger millet varieties

Source of variation	Degree of freedom	Sum of squares	Mean of squares	TSS explained %
Genotypes (G)	8	1322	165.2	9.53
Environments (E)	4	5903	1475.7	42.57
Rep (Env'ts)	10	1675	167.5	12.08
GxE	32	1945	60.8	14.03
IPCA1	11	934	84.9	48.02
IPCA2	9	668	74.2	34.34
Error	80	3023	37.8	
Total	134	13868	103.5	

Table.6 The AMMI model's best finger millet varieties selection per environment

Environments	Grain yield in qt/ha	IPCA1 score	The first four AMMI selections per Environments			
			1	2	3	4
Bedele-2022	35.78	3.43	Gute	Wama	Addis 01	Gudetu
D/Hana-2021	32.68	0.21	Boneya	Gute	Wama	Gudetu
Gechi-2021	17.20	-0.28	Boneya	Wama	Gudetu	Gute
D/Hana-2022	31.32	-1.48	Boneya	Gute	Bareda	Wama
Bedele-2022	33.55	-1.88	Boneya	Wama	Gudetu	Kumsa

Fig.1 Map of the study areas

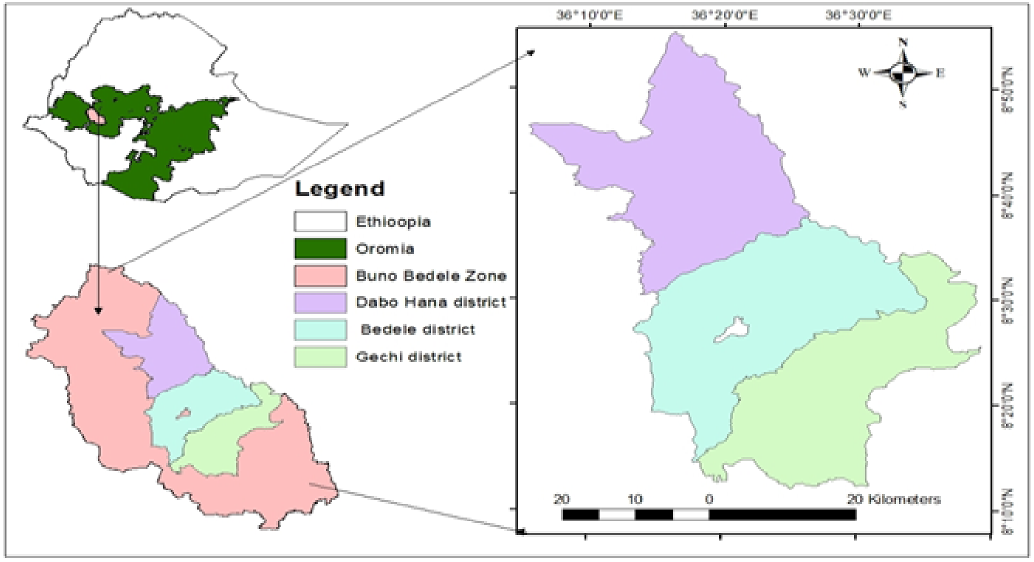


Fig.2 Polygon view of genotype by environment interaction for finger millet varieties

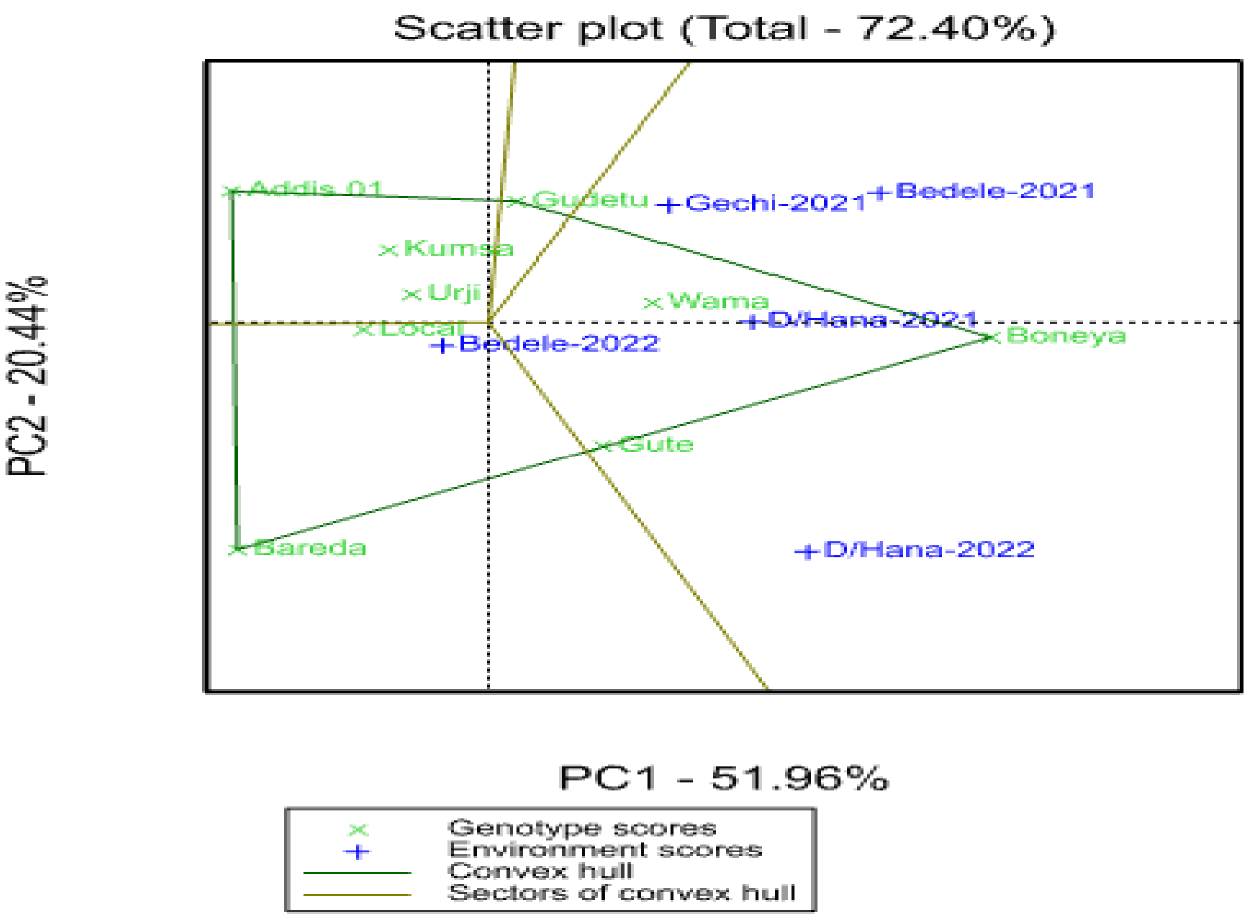


Fig.3 GGE-biplot based on the ranking of varieties for grain yield relative to stable genotype.

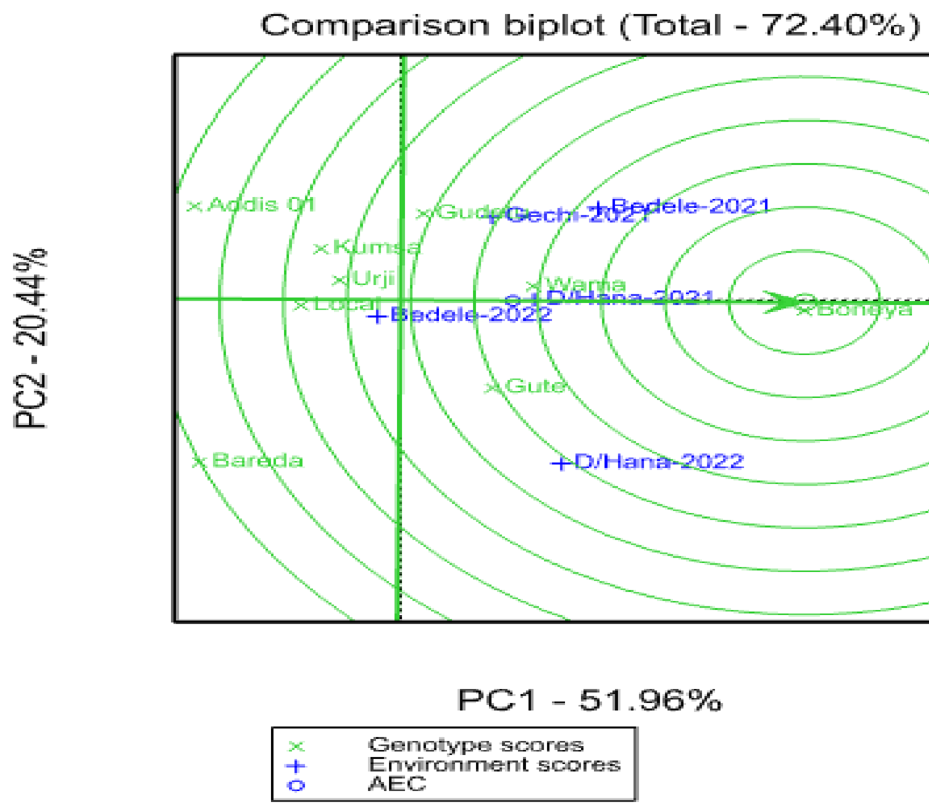
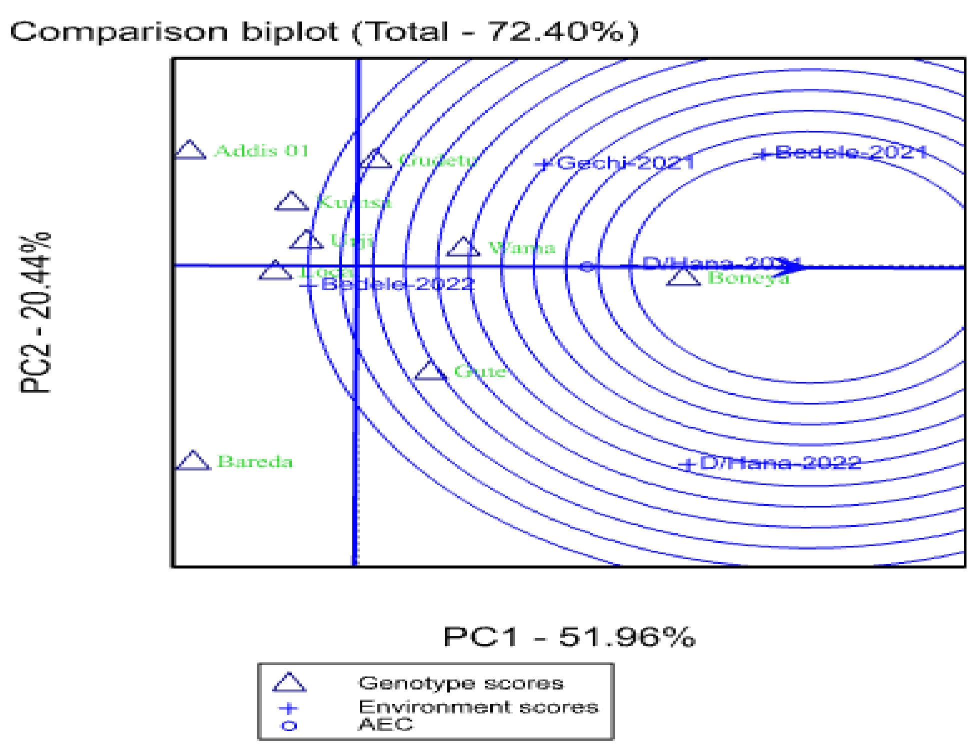


Fig.4 GGE-biplot based on environment- focused scaling for comparison of the environments with the ideal environment



Ranking of genotypes based on mean and stability performance

If a genotype is located closer to the closer to concentric circle, it becomes more desirable than other genotypes which are located far away from the concentric circle. Therefore, concentric circles were drawn around the central circle which contains the stable genotype in order to visualize the distance between each genotype and the stable genotype. From the present study, Wama and Boneya were the stable genotype, with the highest mean grain yield. Similarly, Gute variety was the next located closer to the stable genotype and was considered as desirable variety. Similar result was reported by Abebaw *et al.,* (2020); Kebede *et al.,* (2018).

Discriminating ability and representativeness of environments

According to Yan (2002), discriminating ability and representativeness view of the GGE biplot is the important measure of test environments, which provide valuable and unbiased information about the tested genotypes. Yan and Tinker (2006) also reported that environments 41 with longer vectors had the more discriminating ability of the genotypes, whereas environments with very short vectors had little or no information on the genotype difference. From this study, the test environments D/Hana-2021, Bedele-2021 and Gechi-2021 were identified as the most discriminating environments which provided much information about differences among varieties. Whereas, D/Hana-2022 provided little information about the genotype differences (Fig.4). In harmony, to this (Geleta *et al.*, 2019) on finger millet.

Recommendation

Finger millet is one of the important small seed cereal crop in Ethiopia. It's adaptability to adverse agro-ecological conditions with low input, tolerant to moisture stress and plays a significant role both as food grain and animal feed in areas where production of other cereals are reduced by marginal environments. However, the national average yield in our country is low due to distribution of limited number of improved varieties, moisture stress, lodging effect, diseases, low fertility; poor crop management practices, climatic change and evaluations of the finger millet varieties before release were conducted in limited agro ecologies.

Combined analysis of variance revealed highly significant difference among genotypes, environments and genotype x environment interaction for grain yield. The significant of genotypes x environments interaction effects indicated the inconsistent performance of finger millet varieties across the tested environments. These results illustrated the presence of genetic variability among varieties and the location was diverse. Generally, Boneya and Gute were one of the best genotypes that showed variation on mean grain yield Therefore; these two varieties were recommended and can be used as improved varieties.

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