Agro Bali : Agricultural Journal
Vol. 5 No. 3: 392-402, November 2022

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

Performance Evaluation of Small white Common Bean Genotypes in Eastern Amhara, Ethiopia

Genet Kebede[1♥], Eyeberu Abere[1], Mengstu Tefera[1], Eshetie Wudu[1], Abay Desale[1], Nuru Ahmed[1], Ambachew Tefera[1], Abebe Misganaw[3,] Fantanesh sendekie[2]

[1]Sirinka Agricultural Research Center, Woldia, Ethiopia
[2]Gonder Agricultural Research Center, Ethiopia
[3]Mekidela University, Ethiopia
[♥]Corresponding author email: geniheveny@yahoo.com

Article history: submitted: March 31, 2022; accepted: October 23, 2022; available online: November 26, 2022

Abstract. Common bean regional variety trial was carried out at Sirinka, Jari, Cheffa and West belesa (Gondar) from 2017 to 2019 cropping season. The objectives of the trial were to evaluate the performance of genotypes for grain yield and yield related traits and to select and promote the promising ones for verification. Fourteen genotypes including Awash-2 (standard check) were tested using RCBD. Analysis of variance and GGE biplot analysis was employed on multi-environment grain yield data. The combined analysis of variance showed significant differences for both main and interaction effects of genotypes, locations which led to exploit the significant effect of genotype-by-environment interaction. Based on the analysis of variance and GGE biplot analysis, two varieties namely DAB-413 and ZABR 16575-51 F-22 with average grain yield of 2729 kg/ha and 2501 kg/ha, respectively were selected, verified and DAB-413 and have been released for Sirinka, Jari, Cheffa and similar areas in Ethiopia. Therefore, DAB-413 has been recommended for the tested and other similar common bean growing areas to increase production and productivity of this crop.
Keywords: environment; genotype; grain yield; *Phaseolus vulgaris*; stability

INTRODUCTION

Ethiopia is known as the homeland for several domesticated crop plants(Ephrem Terefe, 2016). It is among the top ten pulse producing countries in the world. Pulses take up 9.69 percent of the country's total grain production and they are the second most important element in the national diet, being the principal protein source and important dietary supplement to cereal consumption (CSA, 2021). Pulses are important mainly for making "wot", an Ethiopian stew, Nifro, Samosa which is sometimes served as a main dish. Pulse has also been used for several years in crop rotation practices. The most important export pulses grown in Ethiopia are Haricot Beans, Chickpeas, Faba beans, Lentils, and Field pea (Chilot et al., 2010).

Pulses are an extremely important crop in food and dietary security. Pulses have about 15% of the total dietary protein utilization in Ethiopia. In Ethiopia pulses are the third largest export crop after coffee and oilseeds (Setotaw et al., 2014). Common beans play a vital role for increasing food security, employment creation and export earnings for the country (FAO, 2015). In terms of composition of export, haricot bean stands first by contributing about 45/% and 43/% of the total grain legumes export volume and value, respectively, followed by chickpea (24%), faba bean (20%) and mung bean (6%) (Setotaw et al., 2014). Fourteen percent of pulse production or 340,000 metric tons was exported, generating $255 million in foreign exchange earnings (GAIN, 2018).

Common bean (*Phaseolus vulgaris L.*) is the largest food legume in the developing world for more than 300 million people (Rangel et al., 2005). It is herbaceous annual crop domesticated independently in Africa, Mesoamerica and later in Europe (FAO, 2015; Ferris & Kaganzi, 2008). Common bean is a very important legume crop cultivated worldwide for its edible bean, popular as dry, fresh and green beans. Based on population growth, demand is growing gradually. Beans provide an alternative to meat as a cheapest source of protein with the highest consumption in poor developing countries. In addition, it provides essential amino acids, minerals and vitamins including iron, potassium, selenium,

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

molybdenum, thiamine, vitamin B6, and folic acid, starch and dietary fiber (Ferris & Kaganzi, 2008). Due to its source of inexpensive protein and rich in minerals (especially iron and zinc) and B-vitamins, beans are often called the "poor man's meat" (Beebe et al., 2000).

Common bean is the most consumed grain legume and provides up to 15% of total daily calories and 36% of total daily proteins in different regions of Africa and the Americas. Moreover, the inclusion in the diet of common beans reduces risk of obesity, diabetes, cardiovascular diseases, and different types of cancer, due to the presence of different beneficial compounds(Cominelli et al., 2019).

Common beans, locally known as „Boleqe" also known as dry bean, Haricot bean, kidney bean and field beans are a major staple food crop in Africa. Common bean is most likely introduced to Ethiopia by the Portuguese in the 16th century (Wortmann, Charles S.; Eledu, 1997). In Ethiopia, it is one of the most important and widely cultivated species of Phaseolus. It is grown predominantly under smallholder producers as an important food crop and source of cash for most Ethiopians and earns foreign currency for the country (Girma Abebe, 2009). It is cultivated primarily for dry seeds, green pods (as snap beans), green leaves, and green-shelled seed. It is consumed as Nifro, Shirowat, soup and samosa. The most commercial varieties are pure red and pure white color beans and these are becoming the most commonly grown types with increasing market demand (Ferris & Kaganzi, 2008).

The major common bean producing areas of Ethiopia are central, southern, eastern and western parts of the country (Girma Abebe, 2009). It grows well from low land (300-1100 m.a.s.l.) to mid-highland areas (1400- 2000 m.a.s.l.) an annual average rainfall ranging from 500–1500 mm with optimum temperature range of 16 °c–24 °c, and a frost-free period of 105 to 120 days (Fikru Mekonnen, 2007).

In general, common bean is recognized as a short season crop (under 100 days) that despite unfavorable climatic or edaphic factors, will always produce seed. Beans do not grow well in hot humid environments. The rainfall below 400mm beans abort their flowers and do not give yield. Throughout modern agricultural history beans have been unrecognized in relation to other crops and in most countries bean production has been pushed on to marginal areas which have less favorable soils that limit production (Kelly, 2010).

All common beans grown in Ethiopia are either bush types, some very determinate or others have an upright short climbing plant similar that permits direct harvest, while others produce a long prostrate vine that is very productive under drier conditions. Small white common beans are one of the common beans which are produced in Ethiopia common bean growing areas. The description of small white common beans is small in seed size (15-25g/100 seeds), white in flower and seed color and which have different growth habits like, determinate bush type, indeterminate type and prostate type.

The current national production of common bean in Ethiopia is estimated at 103,280.55 hectares and 208,295.03 hectares for white and red common bean respectively with total area of 311,575.58 hectares; total production of about 552,564.074 tons per hectare and average productivity of 1.65 tons per hectare (CSA, 2021). Generally, pulses covered 12.9% of the grain crop area; where common bean, faba bean and chickpea accounted for 2.4%, 3.89% and 1.7% respectively. Thus, common bean ranks second next to faba bean in terms of area coverage among pulse crops. The average white and red common bean productivity are 1.79 tons/ha and 1.76 tons/ha respectively. It is predominantly produced in Oromia region, Amhara region and SNNPR with their area coverage of 120,048.28 ha, 89,577.86 ha and 68,548.5ha respectively. The remaining 3.25% is

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

produced in other regions of Ethiopia (CSA, 2021).

Even though the crop has remarkable importance in country economy such as for home consumption, its production improvement is highly challenged by different constraints such as, susceptibility to disease & insect pests, varieties with low potential yield, low soil fertility (mostly N and P), low moisture stress/drought, poor agronomic practices, untimely sowing, suboptimal land preparation, use of low/high seed rates, no/untimely weeding. So, to overcome the challenges listed above, exploiting the existing variability and development of new varieties is crucial. Therefore, the objective of this study was to identify high yielder, relatively disease resistant or tolerant common bean variety.

METHODS

The experiment was conducted at four locations: seven environments Cheffa (environment 1, environment 6), Gonder (environment 2, environment 4), Jari (environment 5), and Sirinka (environment 3, environment 7) bean growing areas of Amhara region during 2017 to 2019.

Treatments and Experimental Design

Experimental materials

Thirteen small white common bean genotypes obtained from Melkasa Agricultural Research center (MARC) including one nationally released variety Awash-2 as a standard check (Table 2).

Table1. Description of the study area

Location	Altitude (m.a.s.l)	Soil type	Ave. rainfall (mm)	Temperature (°C) Min.	Temperature (°C) Max.	Global position Latitude	Global position longitude
Sirinka	1850	Eutric vertisols	1238.8	13.6	27.3	11° 08’	39°28’
Jari	1705	Vertisols	1065.85	13.22	27.43	11° 36’	39° 64’
Cheffa	1465	Vertisols	1119.37	13.4	30.7	10°57’	39° 47’

Source: Sirinka Agricultural Research Centers for altitude, rainfall and soil type; Wikipedia for global position.

Experimental design

The experiment was tested using RCB design with three replications with plot size of 1.6m*4m (6.4m^2). Each plot consisted of four rows with 4m length and 0.4m between rows and 0.1m between plants. The spacing between plots was 0.5m. The amount of seed rate was 80 to kg ha^{-1} required. Other agronomic and protection practices were applied uniformly to the entire experimental area.

Data were collected

Data on plot and plant basis were taken from the central two rows ; days to 50% flowering (DF), days to 90% physiological maturity (DM), plant height (PH in cm), number of pods per plant (NPPP), number of seeds per plant (NSPP), hundred seed weight (gm), grain yield (gm/plot) disease score (1-9 scale) were recorded.

Data Analysis

The grain yield per plot (GY) converted into kg/ha at 12.5% moisture level content. Analysis of variance and GGE biplot was analyzed by using GenStat 18. Software and mean separation were done by using Duncan’s Multiple Range Test (DMRT) at 0.05 % significance. Analysis of variance was done for each environment. Homogeneity of error variances was tested using Bartlett’s test prior to combine analysis over environments. In the analysis, each combination of a single location and year was considered as a separate environment.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

Table2. Description of 14 small white common bean genotypes used for the study

Genotype name	Genotype code	Seed size and color
ZABR 165775-52 F-22	G1	Small white
DAD-221	G2	Small white
SMS-21	G3	Small white
DAB-413	G4	Small white
RAZ-19	G5	Small white
DAB-299	G6	Small white
ZABR 16575-51 F-22	G7	Small white
DAB-479	G8	Small white
ICABUNSI X50	G9	Small white
SEC-20	G10	Small white
NAVY LINE-25	G11	Small white
SMC-25	G12	Small white
SEC-22	G13	Small white
Awash 2	G14	Small white

RESULTS AND DISCUSSION

Statistically significant differences were observed among the tested genotypes in their performance for most measured parameters (Table-3). Number of days to maturity ranged from 82 to 88. Most of the genotypes matured within 85 days. While genotype DAB-479 and genotype SEC-22 took the maximum and minimum days to mature, respectively. The highest number of pods per plant was obtained from SEC-20 (13.35 pods/plant), while the lowest number of pods per plant was obtained from SMC-25 (8.6 pods/plant). Genotype DAB-479 scores the highest number of seeds per pod (5.4). However, the lowest number of seeds per pod (4.09) was obtained from genotype SMC-25. In addition to this, the highest hundred seed weight was recorded at genotype SMC-25 (28.54 g) and the lowest hundred seed weight recorded at DAB-479 (16,29g). Significant variability of number of pods per plant, seeds per pod, branches per plant, plant height, seed yield and hundred seed weight also reported by (Teame Gereziher, 2017). Wide grain yield variation was observed among the genotypes which ranged from 1441 to 2729kg per ha. Genotype DAB-413 gave the highest grain yield (2729kg/ha and weighed (20.36gm / hundred seeds) and Genotype SMC-25 gave the lowest yield (1441kg/ha and weighed 28.54g/hundred seeds). In line with the finding (Shahid & Kamaluddin, 2013; Fahad et al., 2014), it was reported that significant variability was observed for plant height, days to 50% flowering, days to 90% physiological maturity, pods per plant, seed yield per pod, hundred seed weight and yield characters. The standard check, Awash-2 gave grain yield of 2208kg-ha indicating the potential to increase common bean production and productivity in the area.

The mean grain yield of the 14 genotypes ranged from 1441kg/ha to 2729 kg/ha (Table 3). The highly significant genotype differences among these common bean genotypes could be due to differences in their genetic makeup and interaction of environment. DAB-413, ZABR 16575-51 F-22, and NAVY LINE-25 gave higher mean grain yield across locations and SMS-21, SEC-20, ICABUNSI X50, ZABR 165775-52 F-22, DAB-479 gave mean grain yield above the grand mean whereas DAB-299, RAZ-19, DAD-221, SEC-22, and SMC-25 produced grain yield below the grand mean (Table 3).

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

Table 3. Combined grain yield and yield related traits of common bean genotypes tested at four locations during 2017-2019 main cropping seasons.

Genotype	DF	DM	PH	PPP	SPP	100SW	AYKPH	CBB
ZABR 165775-52F22	43.78b^{cde}	85.22^{cde}	48.2^{gh}	11.28^{cd}	5.053^{abc}	18.63^{fg}	2350 ^{bcd}	2 ^{abc}
DAD-221	44.33^{cdef}	83.55^{b}	52.7^{bcde}	11.19^{d}	4.588^{de}	22.79^{b}	1737 ^{fg}	3.167 ^{d}
SMS-21	45.39^{fg}	85.33^{cde}	53.19^{bcde}	12.87^{ab}	5.1^{abc}	16.6^{jk}	2297 ^{bcde}	2 ^{abc}
DAB-413	46.44^{g}	84.61^{bcde}	53.89^{bcd}	12.55^{abc}	5.269^{ab}	20.33^{d}	2729 ^{a}	1.917 ^{ab}
RAZ-19	42.89^{ab}	86.08^{e}	56.72^{ab}	11.78^{bcd}	4.933^{bcd}	19.04^{ef}	1876 ^{f}	2.42 ^{bcd}
DAB-299	45^{ef}	85.56^{de}	55.69^{bc}	11.98^{bcd}	5.117^{abc}	17.2^{ij}	2087 ^{e}	2.17 ^{abc}
ZABR 16575-51 F-22	44.79^{ef}	85.94^{de}	59.6^{a}	10.86^{d}	5.169^{abc}	20.49^{d}	2501 ^{b}	1.667 ^{ab}
DAB-479	46.5^{g}	88^{f}	52.32^{cdef}	11.1^{d}	5.412^{a}	16.29^{k}	2303 ^{bcde}	1.417 ^{a}
ICABUNSI X50	44.11^{bcde}	85.39^{de}	50.77^{defg}	12.02^{bcd}	4.855^{bcd}	17.97^{gh}	2188 ^{de}	2.25 ^{abc}
SEC-20	43.98^{bcde}	84.72^{bcde}	48.02^{gh}	13.35^{a}	5.058^{abc}	17.84^{hi}	2246 ^{cde}	2.17 ^{abc}
NAVY LINE-25	43.49^{abcd}	83.73^{bc}	44.73^{h}	12.22^{abcd}	4.742^{cde}	19.37^{e}	2415 ^{bc}	2.5 ^{bcd}
SMC-25	42.37^{a}	85.16^{cde}	48.54^{fgh}	8.6^{e}	4.097^{f}	28.54^{a}	1441 ^{h}	3.167 ^{d}
SEC-22	44.4^{def}	81.94^{a}	52.99^{bcde}	11.01^{d}	4.701^{cde}	21.29^{c}	1642 ^{g}	2.833 ^{cd}
Awash-2	43.11^{abc}	84.37^{bcd}	49.22^{efg}	11.94^{bcd}	4.379^{ef}	20.89^{cd}	2208 ^{cde}	2.08 ^{abc}
Grand mean	44.33	84.97	51.9	12	4.9	19.81	2144.24	2.268
Genotype	***	***	***	***	***	***	***	***
Location	***	***	***	***	***	***	***	***
Genotype*Location	***	***	***	***	***	***	***	*
CV%	3.7	2.5	11.4	16.3	13.5	5.7	14.6	40

Means followed by the same letter with in column are not significantly different *, ** *** indicate significance at P≤0.05, P≤0.01, and P≤0.001respectively, DF: Days to flowering, DM: Days to maturity, PH: Plant height in cm, NPP: Number of pods per plant, SPP: Number of seeds per pod, 100SW: Hundred seed weight, AYKPH: Adjusted yield in kg per ha, CBB: Common Bacterial Blight

Table 4. Combined analysis of variance for grain yield and yield related traits for 14 small white common bean genotypes evaluated at seven environments in 2017-2019

Source of Variation	d.f	Mean squares						
		DF	DM	PH	PPP	SPP	100SW	AYKPH
Genotype (Gen)	13	27.08***	35.17***	330.24***	27.23***	2.72***	206.90***	2642504***
Location (Loc)	6	599.56***	1627.07***	11216.35***	577.73***	30.44***	440.83***	6524491***
Gen x Loc	78	8.97***	12.66***	132.89***	8.71***	0.81***	2.57***	216602***

The combined analysis of variance showed significant differences both on the main and interaction effects for parameters such as grain yield, days to flowering, days to maturity, number of pods per plant, plant height and hundred seed weight (Table-4). Grain yield and yield related traits of common bean were also affected (P≤0.001)

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

by location, genotype and their interaction which led to undertake mega environment analysis to evaluate the yield and stability of genotypes. Locations differed in their grain yield potential (P<0.001). The average grain yield across locations was 2144.24 kg/ha. The highest mean grain yield was recorded at Gondar 2018 (2699 kg ha^{-1}) followed by Sirinka 2019 grain yield (2411.99 kg/ha) and Jari 2018 grain yield (2384.9 kg/ha). At Cheffa, Gonder and Sirinka 2017 was recorded (1563.93 kg/ha, 1901.62 kg/ha, and 1536.7 kg/ha) respectively below the grand mean (Table 5).

Table 5. Mean grain yield (kg/ha) of common bean genotypes tested at four ocations (Cheffa, Gonder, Jari and Sirinka) over seven environments from 2017 to 2019.

	Genotype	Cheffa 2017	Gonder 2017	Sirinka 2017	Gonder 2018	Jari2018	Cheffa 2019	Sirinka 2019	Mean
1	ZABR 165775-52 F-22	1882^{ab}	2014^{abc}	1953^{bc}	3411^{a}	2548^{abc}	2098^{cde}	2545^{bcd}	2350 ^{bcd}
2	DAD-221	1235^{c}	1540^{cd}	1303^{ef}	2232^{ef}	2048^{bcde}	1732^{e}	2068^{f}	1737^{fg}
3	SMS-21	1598^{bc}	1743^{bcd}	1892^{bcd}	3172^{abc}	2771^{ab}	2117^{cde}	2783^{ab}	2297^{bcde}
4	DAB-413	2189^{a}	2359^{a}	2483^{a}	3118^{abc}	3150^{a}	2770^{a}	3031^{a}	2729^{a}
5	RAZ-19	1470^{bc}	1553^{cd}	1621^{cdef}	2382^{def}	1944^{cde}	2036de	2129^{ef}	1876^{f}
6	DAB-299	1599^{bc}	2142^{ab}	1929^{bcd}	2735^{bcde}	1695de	2078de	2433^{bcdef}	2087^{e}
7	ZABR 16575-51 F-22	2178^{a}	2166^{ab}	2047^{abc}	3232^{ab}	3098^{a}	2585^{ab}	2198^{def}	2501^{b}
8	DAB-479	1488^{bc}	2167^{ab}	2325^{ab}	2600^{cdef}	2624^{abc}	2571^{ab}	2347^{cdef}	2303 ^{bcde}
9	ICABUNSI X50	1274^{c}	2202^{ab}	1808^{bcde}	2966^{abcd}	2646^{abc}	1808^{e}	2611^{bc}	2188de
10	SEC-20	1541^{bc}	2282^{a}	1831^{bcd}	2674^{bcde}	2270^{bcd}	2318^{bcd}	2803^{ab}	2246 ^{cde}
11	NAVY LINE-25	1801^{ab}	2298^{a}	2026^{abc}	2830^{abcd}	2797^{ab}	2442^{abcd}	2708^{abc}	2415^{bc}
12	SMC-25	1151^{c}	1399^{d}	1287^{f}	1218^{g}	1355^{e}	2155^{bcde}	1525^{g}	1441^{h}
13	SEC-22	1209^{c}	1416^{d}	1410^{def}	2029^{f}	1631de	1712^{e}	2090^{f}	1642^{g}
14	Awash-2	1278^{c}	1342^{d}	1801^{bcde}	3185^{abc}	2812^{ab}	2542^{abc}	2496^{bcde}	2208 ^{cde}
	Grand mean	1563.93	1901.62	1836.7	2699	2384.9	2211.62	2411.99	2144.24
	Genotype	***	***	***	***	***	***	***	***
	Location								***
	Genotype*Location								***
	CV%	15.1	13.9	14.9	11.7	17.3	10.7	8.7	14.6

Means followed by the same letter with in column are not significantly different *, ** *** indicate significance at P≤0.05, P≤0.01, and P≤0.001respectively.

GGE Biplot analysis

Mega environment of trial environment

The PC1 and PC2 GGE Biplot were used to estimate pattern of environments as shown in figure 3. Environment PC1 and PC2 scores had positive and negative scores indicating that there was a difference in ranking for yield performance among genotypes across environments leading to a cross over GEI. Visualization of which-won-where pattern of multi - environment trial data is important for studying the possible existence of different mega environment in a region (Yan, 2001). The polygon is formed by connecting the markers of the genotypes that are away from

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

the origin of biplot, such that all other genotypes are contained in the polygon. Genotypes located on the vertex of the polygon performed either the best or poorest in one or more locations since they had the longest distance from the origin of biplot.

Based on the data on table 3, in which-won-where view of GGE Biplot (fig 1) the seven environments fell in two sectors with different winning genotypes. Sector 1 (Mega environment-1) consists of E1, E2, E3, E5, E6, and E7 that have good yielding capacity for genotype G4, G7 and G11. The mega-environment-2 represents E4 that is suitable for genotype G1.

Ranking genotypes relative to ideal genotypes

The ideal genotype should have the highest mean performance and be absolutely stable (Weikai Yan • Manjit S.Kang, 2003), which represented by the small circle an arrow pointing to it (Figure 2). Such an ideal genotype is defined by having the greatest vector length of the high yielding genotype and with zero GEI. Concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype; a genotype is more desirable if it is located closer to the ideal genotype (Mitrovic et al., 2012), so genotype G4 which fell into the center concentric circles was ideal in terms of high yielding ability and stability. In addition, G7 and G11, located on the next consecutive concentric circle, may be regarded as desirable genotypes.

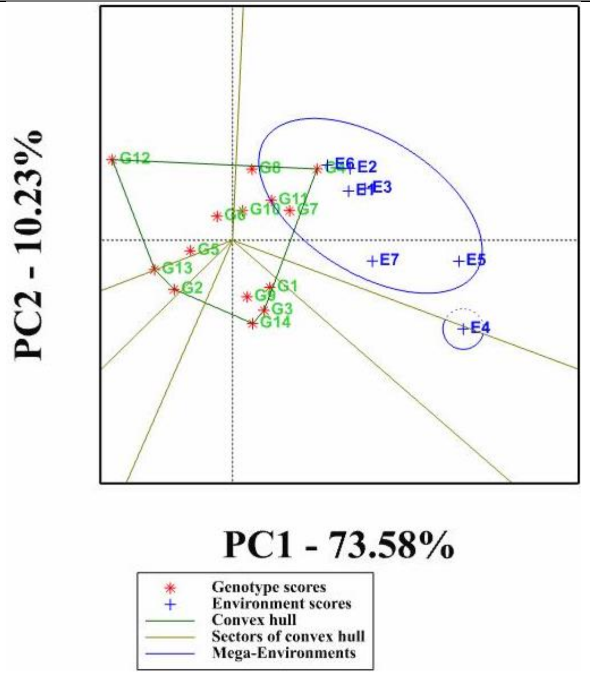

Figure1. GGE biplot identification of winning genotypes and their related mega-environments

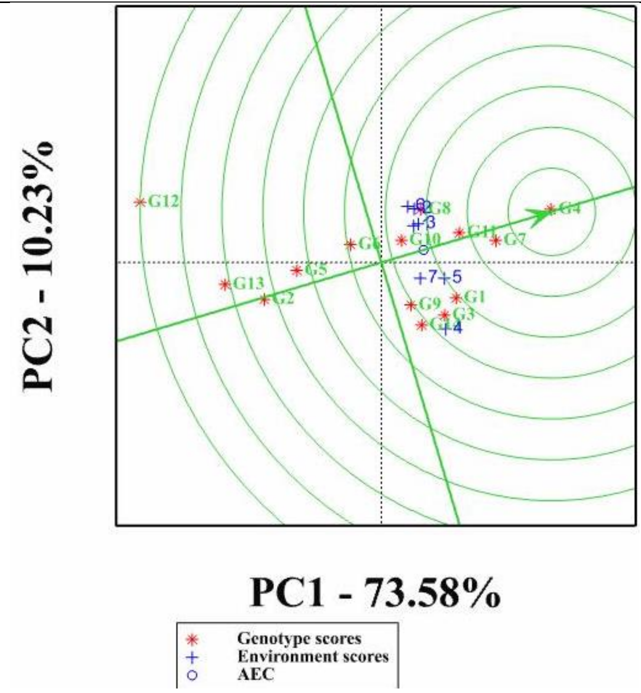

Figure2. GGE biplot based on genotype-focused comparison of the genotype with ideal genotype.

Performance and stability of the genotypes

The yield and stability of genotypes were evaluated by using so-called average environment coordinates (AEC) method (Yan, 2001; Yan, 2002). In this method, the average principal components will be used in all environments and it is presented with a circle, as shown in (Figure 3). The average ordinate environment (AOE) defined by the line which is perpendicular to the average environment axis (AEA) line and pass through the origin. This line divides the genotypes into those with a higher yield

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

than average and into those lower than average (Naheif E. M. et al., 2013).

Thus, G4, G7, G11, G1, G8, G3, G10, G14 and G9 had the highest mean yield and G6, G5, G2, G13 and G12 were the lowest.

The non-arrowed line is AEC; it points to greater variability (poorer stability) in either direction. Thus, G9, G12 and G14 were highly unstable genotypes, whereas G4, G7 and G11 were highly stable.

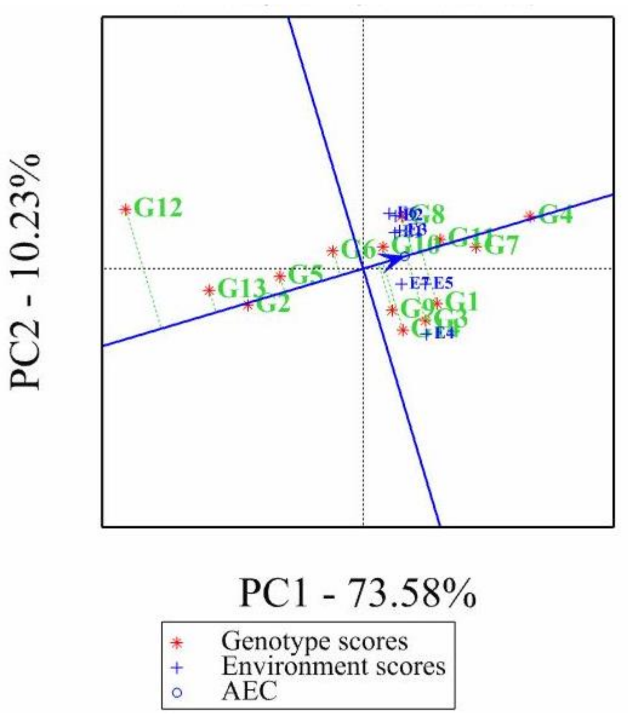

Figure 3. GGE biplot based on environment-focused scaling for mean performance and stability of the genotypes

Discriminating ability and representativeness

The concentric circle on the biplot help to visualize the length of environment vectors, which is proportional to the standard deviation within the respective environments (Yan & Tinker, 2006) (Figure 4).

Therefore, among the nine environments E4, and E5 were most discriminating (informative) and E1, E2, E3 and E6 are least discriminating. The average environment (represented by the small circle at the end of the arrow) has the average coordinates of all the environments, and AEA is the line that passes through the average environment and the biplot origin (Yan & Tinker, 2006). A test environment that has a smaller angle with the AEA is more representative of other test environments. Thus, E5 and E7 are the most representative whereas E4 is least representative. Test environments that are both discriminating and representative are good test environment for selecting generally adapted genotypes.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

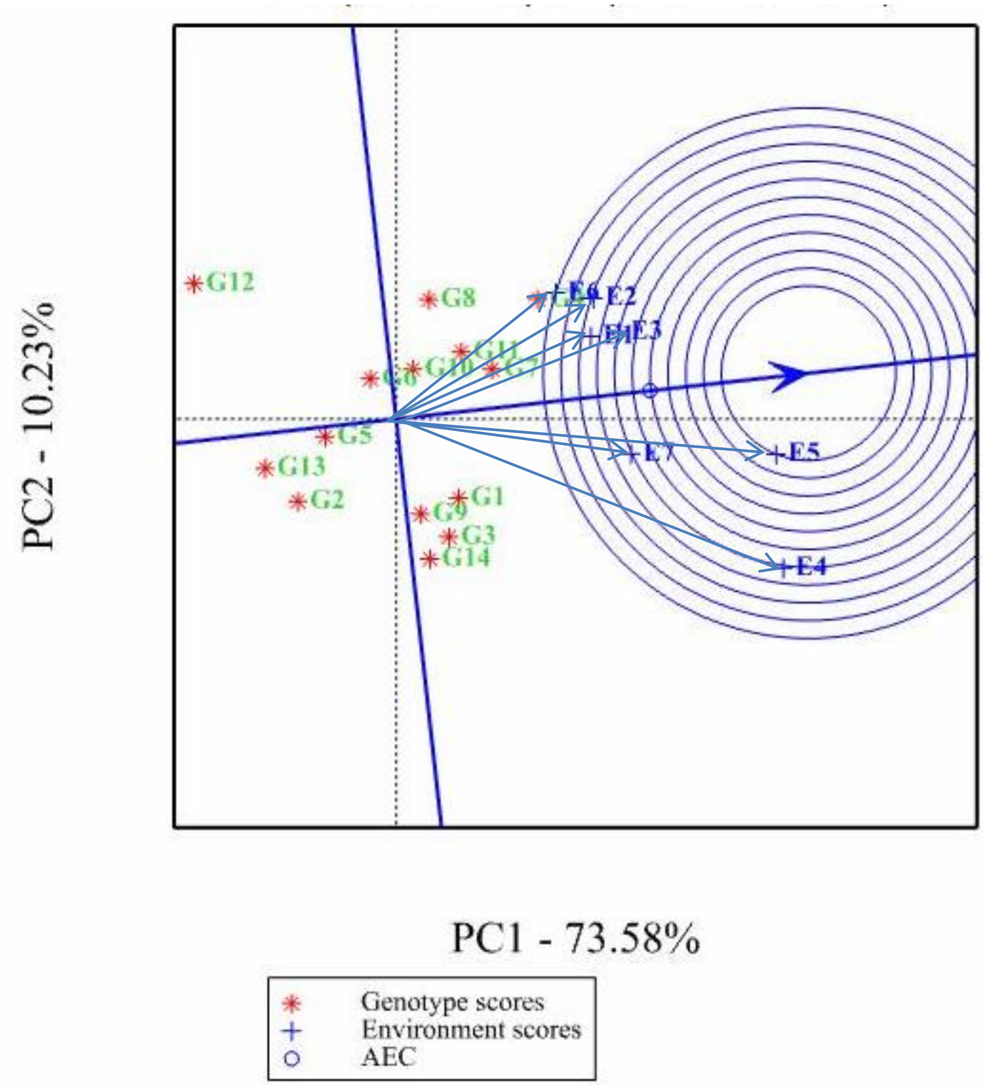

Figure 4. GGE biplot based on environment focused scaling for comparison of the environment with ideal environment.

CONCLUSION

Genotype × Environment Interaction (GEI) has been an important and challenging issue for plant breeders to select superior and adaptable cultivars for growing environments. Both yield and stability should be considered simultaneously to reduce the effect of GEI and to make a selection of genotypes more precise.

The conclusion based on GEI, genotype DAB-413 was high yielder and stable. Among the tested genotypes, DAB-413 has been released for demonstration and pre-scale up production for its better performance in grain yield, relatively disease and drought resistant.

Generally, the current study clearly demonstrates that the application of GGE biplot facilitated the visual comparison and identification of high yielding and stable genotype, thereby supporting decisions of small white bean genotype selected and recommended for the bean growing areas in Eastern Amhara.

REFERENCES

Beebe, S., Skroch, P. W., Tohme, J., Duque, M. C., Pedraza, F., & Nienhuis, J. (2000). Structure of Genetic Diversity among Common Bean Landraces of Middle

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

American Origin Based on Correspondence Analysis of RAPD PER PER. *Crop Science*, *40*, 264–273. https://doi.org/https://dx.doi.org/10.2135/cropsci2000.401264x

Chilot, Y., Shahidur, R., Befekadu, B., & Solomon, L. (2010). *Pulses Value Chain Potential in Ethiopia Constraints and opportunities for enhancing exports* (No. 276; Gates Open Resource 3).

Cominelli, E., Rodiño, A. P., Ron, A. M. De, & Sparvoli, F. (2019). Genetic Approaches to Improve Common Bean Nutritional Quality : Current Knowledge and Future Perspectives. *Springer Nature Switzerland*, 109–138. https://doi.org/10.1007/978-3-030-04609-5

CSA. (2021). Report on Area and Production of Major Crops. In *The Federal Democratic Republic of Ethiopia Central Statistical Agency (CSA)* (Vol. 1).

Ephrem Terefe. (2016). Review of Haricot bean Value Chain in Ethiopia Review of Haricot bean Value Chain in Ethiopia. *Jornal of Asian and African S*, *24*.

Fahad, A., Alshatri, N., Tari, Z., Alamri, A., Khalil, I., Zomaya, A. Y., Foufou, S., & Bouras, A. (2014). A Survey of Clustering Algorithms for Big Data : Taxonomy and Empirical Analysis. *IEEE Transactions on Emerging Topics in Computing*, *2*(3), 267–279. https://doi.org/10.1109/TETC.2014.2330519

FAO. (2015). *Analysis of price incentives for haricot beans in Ethiopia for the time period Analysis of price incentives for haricot beans in Ethiopia for the time period* (A. M. A. and B. L. Tadesse Kuma Worako (ed.)). MAFAP.

Ferris, S., & Kaganzi, E. (2008). *Evaluating marketing opportunities for haricot beans in Ethiopia* (No. 7).

Fikru Mekonnen. (2007). Haricot ban (Phaseolus Vulgaris L.) variety dvelopment in the lowland areas of Wollo. In and W. B. Ermias Abate,Akalu Teshome,Alemayehu Asefa , Melaku Wale, Tilahun Tadesse (Ed.), *Proceeding of the 2nd Annual Regional Conference on Completed Crops Research Activities* (pp. 86–93). Amhara Regional Agricultural Research Institute.

Food and Agriculture Organization (FAO). (2015). *Food Balance Sheets*. FAOSTAT.

GAIN. (2018). *Pulse Crops Market Update* (Vol. 17). GAIN (Global Agricultural Information Network).

Girma Abebe. (2009). … Moisture Conservation on the Yield and Yield Components of Haricot Bean (Phaseolus Vulgaris L .) In the Semi Arid Zones of the Central Rift Valley in O RIGINAL A RTICLE Effect of Np Fertilizer and Moisture Conservation on the Yield and Yield Components. *Advances in Environmental Biology*, *3*(3), 302–307.

Kelly, J. D. (2010). *The Story of Bean Breeding*. *June*, 30.

Mitrovic, B., Stanisavljevi, D., Treski, S., Stojakovic, M., Ivanovic, M., Bekavac, G., & Rajkovic, M. (2012). Evaluation of Experimental Maize Hybrids Tested in Multi-Location Trials Using Ammi and GGE Biplot Analyses. *Turkish Journal of Field Crops*, *17*(1), 35–40.

Naheif E. M., M., Alaa A., S., & Amein, and K. A. (2013). Additive main effects and multiplicative interaction (AMMI) and GGE-biplot analysis of genotype × environment interactions for grain yield in bread wheat (Triticum aestivum L .). *African Journal of Agricultural Research*, *8*(42), 5197–5203. https://doi.org/10.5897/AJAR2013.6749

Rangel, A. F., Mobin, M., Rao, I. M., & Horst, W. J. (2005). Proton toxicity interferes with the screening of common bean (Phaseolus vulgaris L.) genotypes for aluminium resistance in nutrient solution. *Journal of Plant Nutrition and Soil Science*, *168*(4), 607–616. https://doi.org/10.1002/jpln.200520509

Setotaw, F., Yigezu, A. Y., Seid, K., & Aden, A. (2014). *Trends in Global and National Grain Legume Production and Trade: Implications on Local Chickpea and Lentil Production Dynamics: The Case of Gimbichu and Minjar-Shenkora Districts of Ethiopia.*

Shahid, A., & Kamaluddin. (2013). Correlation and path analysis for agro-morphological traits in rajmash beans under Baramulla-Kashmir region. *African Journal of Agricultural Research*, *8*(18), 2027–2032. https://doi.org/10.5897/ajar2012.0014

Teame Gereziher, E. S. and G. B. (2017). Performance evaluation of common bean

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v5i3.948

(Phaseolus vulgaris L.) varieties in Raya Valley, Northern Ethiopia. *African Journal of Plant Science*, *11*(1), 1–5. https://doi.org/10.5897/ajps2016.1464

Weikai Yan • Manjit S.Kang. (2003). GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists, and Agronomists. In Duane E. Falk (Ed.), *Crop Science*. CRC PRESS Boca.

Wortmann, Charles S.; Eledu, C. A. (1997). *Distribution of bean seed types in Eastern Africa.*

Yan, W. (2001). GGEbiplot — A Windows Application for Graphical Analysis of Multienvironment Trial Data and Other Types of Two-Way Data. *Agronomy Journal*, *93*(5), 1111–1118.

Yan, W. (2002). Singular-Value Partitioning in Biplot Analysis of Multienvironment Trial Data The Model for a GGE Biplot. *Agronomy Journal*, *94*(5), 990–996.

Yan, W., & Tinker, N. A. (2006). Biplot analysis of multi-environment trial data : Principles and applications. *Canadian Journal of Plant Science*, *86*(3), 623–645.