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Research Article

Performance Evaluation of Small white common bean (*Phaseolus vulgaris L.*) Varieties at Buno Bedele and Ilu Aba Bora Zones, South-western Oromia

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Abstract

The field experiment was conducted at two districts of Buno Bedele zone (Bedele & Dabo Hana) and one district of Ilu Aba Bor zone (Bure) in south-western Oromia for two years (2023-2024 G.C). The objective of this study was to select adaptable, stable, higher yield and disease resistant small white common bean varieties. In the experiment, six improved small white common bean varieties and one local check were laid out in randomized complete block design (RCBD) with three replications. Phenological, growth, yield and yield related traits data were collected and analyzed by R-software. Grain yield and yield related traits were significantly affected by main effect of variety, environment and variety-environment interaction. The results revealed that, there were significant at ($p < 0.001$) variations between the varieties for yield, number seed per pod and days to maturity whereas significant at ($p<0.01$) for days to flowering, plant height and number of pod per plant. Thus, higher grain yield was recorded from Awash mitin (2330.51 kgha^{-1}) followed by Wabero (1878.11 kgha^{-1}), while lower grain yield was recorded from Awash-1 (1261.36 kgha^{-1}). The AMMI analysis shown that 14.92% of the total sum of squares (SS) was contributed to environments (E), 25.76% to the genotypes (G) and 23.08% to GEI effects. Principal component 1 and 2 accounted for 73.80% and 15.01% of the GEI respectively with a total of 88.81% variation. Therefore, as compared to the others, those two small white common bean varieties were recommended as promising varieties to the farmers of study areas.

Keywords: Small white common bean; Grain yield; Varieties; RCBD and AMMI

Introduction

Common bean (*Phaseolus vulgaris* L; 2n= 22) is a diploid self-pollinated plant that goes to the genus Phaseolus in the Fabaceae family [1], which has more than 80 cultivated and wild species in the world [2]. Common bean is the most vital food and cash crops worldwide [3]. Common bean is very favored by Ethiopian farmers because of the possibility of maturing by around two months that enables households to get cash returns vital to pay for food and other household needs when other crops have not yet matured [4]. Early maturity and moderate degree of drought tolerance led the crop's vital role in farmers' strategies for risk aversion in drought prone lowland areas of the country [5].

In Africa, the major common bean producing countries include Burundi, DR Congo, Ethiopia, Kenya, Rwanda, Tanzania and Uganda, indicating that East Africa is the most suitable bean production region on the continent [6,7]. Common bean is the most broadly cultivated in Ethiopia which covered 18.6% of land with 17.3% of grain production from pulse crops produced in 2021 [8]. In Ethiopia, common bean covered about 339,350.34 hectares of land and 584,157.99 tons of grain was produced per annum in 2022 with average productivity of 1.72 tons per hectare [9]. As the demand of common bean production is increasing in alarming rate, the area of production increasing from 280,834.99 ha in 2020 to 339,350.34 ha in 2022 [9].

There are widespread kinds of common bean types grown in Ethiopia including mottled, red, white and black varieties [10]. The most profitable varieties are pure red and pure white color beans and these are fetching the most commonly grown types with increasing market demand [11]. Among zones in south-western Oromia, the production of common bean is concentrated in the lowlands of Buno Bedele and Ilu Aba Bora zones, specially Dabo Hana, Bedele and Bure districts due to the presence suitable environments to this crop. However, lack of improved varieties of small white common bean is the major problem for low production and productivity of the crop in the study areas. Therefore, the study was initiated to identify and recommend suitable high yielder and disease tolerant small white common bean varieties for the study areas and similar agro ecologies in south-western Oromia, Ethiopia.

Materials and Methods

Experimental Site

The experiment was conducted under rain fed condition at Bedele, Dabo Hana and Bure districts which are far 483 km, 521 km and 683 km from Addis Ababa respectively during 2023 and 2024 main cropping season. These locations represent the major common bean producing areas of South-western Oromia regional state (Table 1).

Experimental Materials and Design

A total of six improved small white common bean varieties (Mex-142, RAZ-42, Awash-1, Awash melka, Awash mitin and Wabero) including one local check were used as planting materials. The experiment was tested using a randomized completed block design (RCBD) with three replications. The experimental plots were 6 m² (3m × 2m) in size, with five rows separated by 0.4m. The distance between plots and blocks was 0.5 m and 1m, respectively. Out of five rows, the middle three rows were used for data collection and the two outer most rows were used as border rows. The experimental sites were plowed three times with draught animals called oxen before planting, and 100 kg ha⁻¹ seed rate and 100 kg ha⁻¹ of NPS fertilizer rate were used according to crop recommendations. Other agronomic and protection practices were applied uniformly to the entire experimental area (Table 2).

Table 1: Years, sites, codes, coordinate status of the environment long term of precipitation.

Years	Sites	Codes of sites	Altitude (masl)	Latitude	Longitude	Annual Rf. (mm)
2023	Bedele	E1	1300-2200	8°14'N	36°13'E	1200-1800
	Dabo Hana	E3	1190-2323	8°43'N	36°26'E	900-2200
	Bure	E5	1530-2000	8°18'N	36°31'E	1000-2000
2024	Bedele	E2	1300-2200	8°14'N	36°13'E	1200-1800
	Dabo Hana	E4	1190-2323	8°43'N	36°26'E	900-2200
	Bure	E6	1530-2000	8°18'N	36°31'E	1000-2000

Table 2: Description of small white common bean varieties used in the experiment.

Varieties	Seed size and Color	Year of Release	Source
Mex-142	Small white	2016	MARC/EIAR
RAZ-42	Small white	2019	MARC/EIAR
Awash-1	Small white	2012	MARC/EIAR
Awash melka	Small white	2004	MARC/EIAR
Awash mitin	Small white	2017	MARC/EIAR
Wabero	Small white	2018	SARC/OARI
Local	Small white	-	Farmer

Source: Crop variety register.

Data Collection and Statistical Analysis

Experimental data were collected on individual plant basis for plant height, number of pods per plant, number of seeds per pod while on plot basis were collected on days to flowering, days to maturity, grain yield and disease data. The analysis of variance (ANOVA) for each location and combined analysis of variance over locations were performed using the R software and the mean separation was done using Least Significant Difference (LSD) at the 5% probability level. The linear mixed model was used in the analysis of variance to combine over locations.
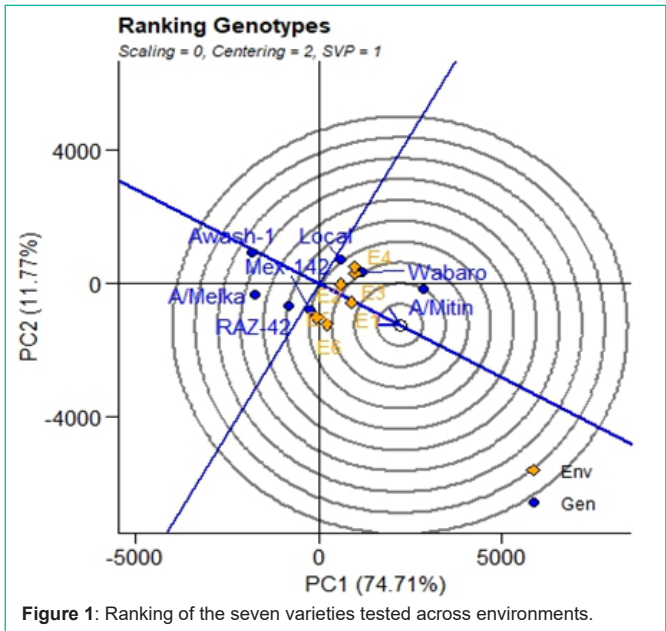

Figure 1: Ranking of the seven varieties tested across environments.

GGE Bi-plot and AMMI Stability Analysis

The GGE bi-plot was used to evaluate the test genotypes and environments. An environment is considered ideal for genotype testing when it discriminates the genotypes and represents the environments [12]. The presence of correlation between two environments means that similar information about the genotype performance is derived from them and therefore could be an option to reduce the number of test environments. In addition, GGE bi-plot is an effective visual tool for identifying the mega-environment issues and showing the specific adaptation of the genotypes and which cultivar won in which environments [13]. A mega-environment is defined as a group of locations that steadily share the same best cultivar [14].

Results and Discussion

Combined Analysis of Variance

The analysis of variance for the measured traits of the tested varieties showed there were significant differences at (p<0.05 and p<0,001). The analysis of variance for the measured traits of the tested varieties showed there were significant differences for both main effect of variety and locations in all parameters. The interaction of variety and location showed significant difference (p<0.001) days to flowering, days to maturity, number of pod, per plant, seed per plant and grain yield but not for plant height (Table 3). Hence, the parameters were varying among varieties over locations. The observed differences among the varieties could be due to variation in the genetic makeup of these varieties and influence of environmental factors. The highly significance difference for grain yield among the locations, varieties and interaction indicates that the environments have different impact on the yield potential of the varieties though the varieties have different performance in the tested environments. The mean yield potential of the varieties varying across environments and among varieties indicating the varieties were expressing their potentials even though they were affected by environments and genetic variations. The same results were reported by Perreira et al., [15] and Perreira et al. [16] which indicated that common bean varieties can have different response and interact highly to environmental variation.

Table 3: ANOVA for yield and yield related traits for seven (7) small white common bean varieties.

Source of variation	Df	Mean squares					
		DF (days)	DM (days)	PH (cm)	NPP	NSP	GY (kgha^{-1})
Replication	2	4.15^{ns}	10.70^{ns}	40.30^{ns}	1.99^{ns}	0.71^{ns}	383540^{ns}
Varieties	6	96.16***	904.95***	519.51***	26.75*	12.83**	7739218***
Location	2	207.65***	605.58***	2930.73***	305.14***	3.79*	9808114***
Var : Loc	12	41.49**	162.69***	214.85^{ns}	29.55**	1.89*	2283137***
Var : Year	6	272.82***	624.60***	1272.01***	281.08***	7.23**	1357279***
Residual	82	22.56	34.4	101.59	29.26	1.22	279993

Note: SOV=Source of Variations, Df=degrees of freedom, DF=days to flowering, ,DM=days to maturity, PH=Plant height, NPP=number of pod per plant, NSP=number of seed per pod *** significant (0.001), *=significant at (0.05) & ns= non-significant.

Table 4: Combined mean grain yield (kg ha^{-1}) of seven (7) small Common bean varieties tested at Bedele, Dabo Hana and Bure districts for two years (2023-2024).

Varieties	Buno Bedele		Ilu Aba Bora		
	Bedele	Dabo Hana	Bure	Overall Means	YA (%)
Mex-142	2031.66^{ab}	1765.51^{bcd}	1053.06^{bc}	1616.74^{bc}	-2.81
RAZ-42	1840.51^{bc}	1645.91^{cd}	1391.39^{ab}	1626.58^{bc}	-2.22
Awash-1	1413.54^{cd}	1289.99^{d}	663.89^{c}	1261.36^{c}	-24.17
Awash melka	1211.88^{d}	1226.13^{d}	985.28^{bc}	1307.76^{c}	-21.38
Awash mitin	2559.10^{a}	2886.61^{a}	1712.50^{a}	2330.51^{a}	40.1
Wabero	2010.75^{ab}	1883.85^{bc}	1393.33^{ab}	1878.11^{b}	12.9
Local	1619.13^{bcd}	2222.36^{b}	1148.89^{abc}	1663.46^{bc}	0
Mean	1812.37	1845.77	1192.62	1668.5	
LSD (0.05)	567.65	548.08	623.47	415.19	
CV (%)	26.66	27.27	29.5	31.65	
P-value	***	**	*	***	

*Note: LSD=least significant difference, CV= coefficient of variation, NS=non-significant, *, ** and ***, significance at 0.05, 0.01 and 0.001 probability levels respectively and YA=yield advantage*

Performances of Small White Common Bean Grain Yield Across Locations

The analysis of variance revealed a highly significant difference (p<0.001) among the varieties in all locations for grain yield (Table 4). According to the result, the highest mean grain yield was exhibited by the variety Awash mitin (2330.51kgha^{-1}) followed by Wabero (1878.11kgha^{-1}), whereas, the lowest grain yield performance was recorded for variety Awash-1 (1261.36 kgha^{-1}).

The high yielder variety at most locations was found with Awash mitin variety which indicates the presence of genetic potential for resistance of varies stress conditions for creating this stability of yield potential across locations. Generally, the varieties respond differently to diverse environments leading to the essence of identification of a potential variety for specific location. Similarly, the existence of wide genetic variation in grain yield and yield components of common bean has been reported by various authors [17,18].

Performances of Agronomic Phenology, Growth and Yield Related Traits

The combined analysis of variance over the two seasons revealed a highly significant (P < 0.01) difference in flowering days, maturity days, height of the plant, number of pod per plant and number of seed per pod between the studied varieties (Table 4). This finding suggests that genotypic variability exists among the small white common bean varieties studied and the traits under consideration.

Days to Flowering (DF)

Days to flowering and maturity are among the most vital characteristics that need to be considered in selecting varieties when and where the lack of rainfall is limiting factor for further enhancement of yield and yield related traits. The earliness trait (days to flowering and days to physiological maturity) enables crops to flower and mature early, escaping from moisture stress that results in reduced yield. According to this study, the mean of days to flowering over location was ranged from 35.00 to 45.33 from Awash-1 and Local check respectively.

Days to Maturity (DM)

There was significant variation (P < 0.01) in yield components among the small white common bean varieties in the combined analysis over location (Table 4) at all sites. The interaction of variety with location also significantly affected days to physiological maturity and grain yield in the combined analysis. Among the tested varieties the Wabero and Awash mitin were early matured with respective values of 71.20 and 72.40 days. On the other hand, Local check and RAZ-42 had longest time of maturity with respective values of 89.20 and 82.27 days (Table 4). This indicated that, the advantage of those varieties for escaping moisture stress condition of study area. Tigist et al. [7] studied on 144 genotypes of common bean at three locations of Oromia region and indicated that days to maturity showed a significant difference between varieties, locations and GXE interactions.

Number of Pods per Plant (NPP)

The interaction of small white common bean varieties with different locations revealed a highly significant (p<0.01) difference on number of pods per plant (Table 4). The higher number of pods per plant was recorded from Awash mitin (24.19) followed by Wabero (18.03) as compared to other testing varieties, whereas the lowest was obtained from Awash-1 variety (13.17) However, it is difficult to conclude increment number of pod per plant can be increase yield per hectare; because total yield also influenced by the yield harvested from individual plant and number of plants per hectare. Etana and Nebiyu [2] reported that number of pods per plant showed significant difference between four studied common bean varieties, of which, two from farmers cultivars and two from improved varieties

Number of Seeds per Pod (NSP)

The varieties and locations alone revealed a highly significant difference on number of seeds per pod (Table 4). Maximum number of seeds per pod was recorded from Awash mitin (7.18) variety followed by Wabero (6.68) variety. Whereas, the lowest number of seeds per pod (4.18) was obtained with local check. This variation could be due to genetic inherent of those improved small white common bean varieties produced more number of seeds per pod. Etana and Nebiyu [2] also reported that number seeds per pod showed a highly significant difference between the varieties in common bean.

Plant Height (PH)

There was significant difference among the verities for plant height. Maximum plant height was noted in variety RAZ-42 (75.40cm) followed by Mex-142 (74.65cm), whereas; the lowest plant height was recorded in local variety (64.61 cm).

Table 5: Combined ANOVA of yield related traits for seven small Common bean Varieties.

Varieties	DF (days)	DM (days)	PH (cm)	NPP	NSP	Dis. (AB)
Mex-142	39.80[bcd]	76.87[bc]	74.65[a]	14.70[bc]	5.98[bc]	40ms
RAZ-42	43.40[ab]	82.27[ab]	75.40[a]	16.63[bc]	6.48[abc]	20mr
Awash-1	35.00[d]	76.87[bc]	62.08[b]	13.17[c]	5.79[c]	40ms
Awash melka	42.60[abc]	75.67[bc]	65.76[ab]	15.02[bc]	5.80[c]	40ms
Awash mitin	41.60[abc]	72.40[c]	65.44[ab]	24.19[a]	7.18[a]	20mr
Wabero	37.47[cd]	71.20[c]	62.17[b]	18.03[b]	6.68[ab]	20mr
Local	45.33[a]	89.20[a]	67.15[ab]	14.83[bc]	4.18[d]	40ms
Mean	40.74	77.78	67.52	16.65	6.01	
LSD (0.05)	5.44	7.17	11.41	4.43	0.85	
CV (%)	18.43	12.72	23.32	26.72	19.5	
P-value	**	***	**	**	***	

*Note: DF= days to flowering, DM= days to maturity, PH= plant height, NPP= Number of pod per plant, NSP= Number of seed per pod, AB=Aschochyta Blight, LSD=least significant difference, CV= coefficient of variation, NS=non-significant, ** & ***, significance at 0.01 and 0.001 respectively.*

Table 6: AMMI analysis for grain yield of seven (7) small white common bean varieties.

SOV	Df	SS	MS	Variance (%)	Cumulative (%)
REP (ENV)	12	1809405.1	150783.76[ns]		
ENV	5	26899201.2	5379840.24**	14.92	
GEN	6	46435309.5	7739218.25**	25.76	
GEN: ENV	30	41599860.1	1386662.00**	23.08	
PCA-1	10	30699606.7	3069960.67**	73.8	73.8
PCA-2	8	6245486	780685.75*	15.01	88.81
Residuals	72	21917118	304404.42		
Total	155	180260754.2	1162972.61		

*Note: *** Significant difference at (P≤0.001), SOV=source of variation, Df=degree of freedom, SS=sum of square, MS=mean sum of square, PCA= principal component of axis.*

Reaction to Major Diseases

The major common bean diseases according to their importance in the growing areas are rust, anthracnose and bacterial blight rust are the most important ones among the various diseases that affect the crop. In 1-9 rating scale, Awash mitin, Wabero and RAZ-42 scored 3 (moderately resistant) for all the above mentioned diseases. The varieties are characterized by moderately resistance types of reaction to these major diseases at all the sites (Table 5).

Additive Main Effects and Multiple Interaction (AMMI) model

The AMMI analysis of variance of seven (7) small white common bean tested over six environments revealed that 14.92% of the total sum of squares (SS) was contributed to environments (E), 25.76% to the genotypes (G) and 23.08% to GEI effects (Table 6). A large SS for environments indicated that the genotypes were diverse with large differences among the means. The magnitude of G x E SS was close to that for the SS for G, thus indicating that the differences in the response of the genotypes across environments were noteworthy.

The first principal component axis (PCA-1) accounted for 73.80 % of the interaction SS in 19.35% of the interaction degrees of freedom and PCA-2 explained further 15.01% of the interaction SS (Table 5). The mean square (MS) for both IPCA-1 and IPCA-2 were significant at P<0.01 and p<0.05 levels respectively and cumulatively paid to 88.81% of the total interaction.
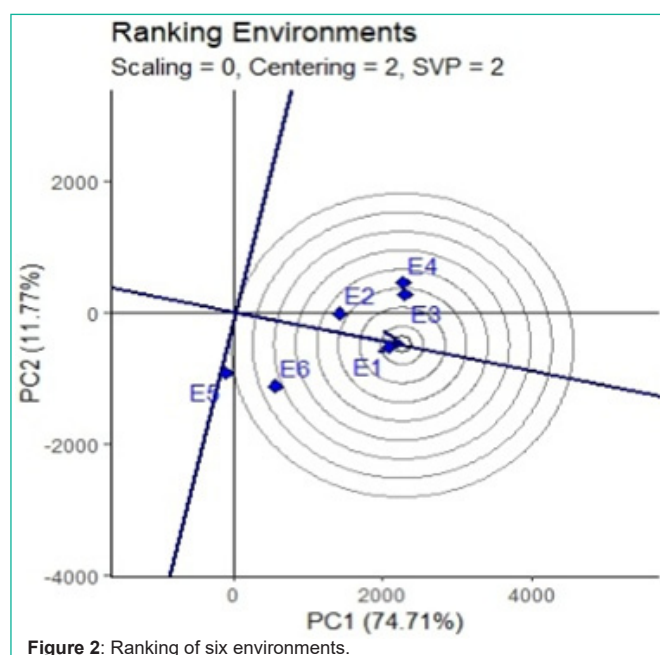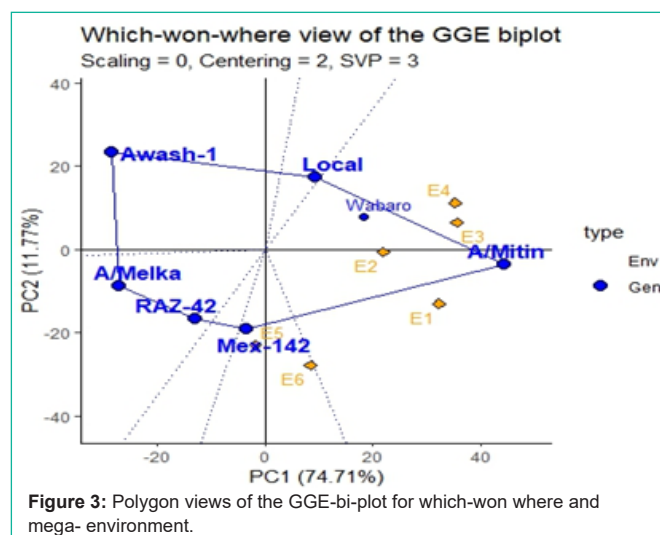

Figure 2: Ranking of six environments.

GGE Bi-plot Analysis

GGE bi-plot is important to visualize the genotype by environment interaction. The GGE bi plot graphic analyses of the seven small white common bean varieties tested across six environments are presented in the figures below.

Ranking Genotypes

Stability can be identified using concentric circles and also ideal genotypes are at the center of the concentric circle. The ideal genotype is the one that with the highest mean performance and absolutely stable [12]. The genotypes that are closer to the ideal genotypes are the best performing genotypes. Hence, the GGE bi plots shows that Awash mitin is an ideal variety, with other varieties like Wabero and Local are desirable varieties as they are closer to the ideal variety on the bi plot. The varieties Awash-1 and Awash-melka are the most undesirable varieties as they are too far to the ideal variety on the bi plot.

Figure 3: Polygon views of the GGE-bi-plot for which-won where and mega- environment.

Ranking of Environment

The most representative of the environments (ability to represent the mega environment) and the most powerful to discriminate varieties reported that the ideal environment is the one located at the center of the concentric circles, and it is possible to identify desirable environments based on their closeness to the ideal environment. Therefore, Among the test locations, location E1 which fell into the center of concentric circles was an ideal test location in terms of being the most representative of the overall environments and the most powerful to discriminate the performance of the tested genotypes.

Next to the first concentric circle location, environments E3, E4 and E2 are close to the best environment while, environments E5 and E6 are noticed as the weakest locations to classify varieties (Figure 2).

Which-Won-Where Pattern

The polygon view of GGE bi-plot indicates the best genotypes in each environment and group of environments [14]. The polygon is formed by joining the genotypes that are farthest away from the bi-plot origin, such that all the other genotypes are contained in the polygon. In this case, the polygon connects all the farthest genotypes and perpendicular lines divide the polygon into sectors. Sectors help to visualize the mega-environments. This means that winning genotypes for each sector are placed at the vertex. Polygon view of the small white common bean varieties tested at six environments locations presented in (Figure 3). Hence, Awash-1, Awash melka, RAZ-42, Mex-142, Awash mitin and local varieties were the vertex small white common varieties. From this figure, Wabero, Awash-mitin and Local varieties well performed at E4, E3, E2 and E1 in the first mega environment. In the second mega environment Mex-142 variety was good performed at E5 and E6. From the figure, Awash-1, Awash melka and RAZ-42 had no environment on the vertex. This indicates that varieties in the vertex without environment performed poorly in all the locations.

Conclusion and Recommendation

Common bean is one of Africa's most vital pulses. The adaptation of common bean varieties to drought-stress situations is very crucial for drought vulnerable areas particularly lowland parts of Ethiopia. The crop provides vital nutrients as a food including vitamins, proteins, minerals and the stems are also used as fodder for livestock, especially in the dry spell following the main cropping season. As a legume, common bean plants also contribute to soil fertility enhancement through atmospheric nitrogen fixation.

The present study shown the presence of genetic variability among varieties with respect to different traits. The presence of significant difference among common bean varieties for the studied traits ensured the presence of large genetic variation to be improved through selection. Plant breeding is primarily depending on presence of substantial genetic variation to address the maximum genetic yield potential of the crops and exploitation of these variations through effective selection for further improvement.

Analysis of variance showed highly significant varietal differences days to flowering, plant height and number of pod per plant at 1% probability level and very highly significant difference observed for days to maturity, number of seed per pod and grain yield 0.1% probability level. The combined means result indicated that the Awash mitin (2330.51kgha⁻¹) and Wabero (1878.11kgha⁻¹) small white common bean varieties had the highest yield respectively. Thus, Awash mitin and Wabero were identified as the best varieties in terms of yield, stability, tolerant to diseases and better agronomic performance. Hence, as compared to the others, those two small white common bean varieties were recommended as promising varieties to the farmers of study areas with similar agro-ecologies based on their optimal yield performance for further adoption.

Acknowledgments

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