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Evaluation and Stability Analysis of Small Seeded Common Bean (*Phaseolus vulgaris* L.) Varieties at Selected Districts of Central Ethiopia

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ABSTRACT

Background and Objective: One of the most significant gaps in the Central Ethiopia Region is low common bean productivity. The evaluation and stability analysis of common bean varieties were critical to enhancing production and productivity in the area. This study aimed to identify high-performing small-seeded common bean varieties with wide and specific adaptability. **Materials and Methods:** The experiment took place in the Central Ethiopia Region of Abeshge, Sankura, and Mareko Districts during the 2020-2021 Agricultural season. This experiment included eight varieties: Awash-1, Awash-2, Awash-Meten, Rore, Hawassa-Dume, Nasir, SER-119, and SER-125. This experiment was conducted using RCBD with three replications. Pods per plant, seeds per plant, seeds per pod, and primary branches per plant were collected. Plant height, hundred seed weight, and yield data were all measured. Data was analyzed by using R-Software version 3.4. **Results:** The combined study of seed yield variance found that location, variety, and location-by-variety interactions all had a significant effect. Across all studied areas, the SER-125 variety had the highest mean yield. The AMMI analysis produced one significant (PCA 58.70%) component of the total variation. The ANOVA, mean yield performance, AMMI analysis, AMMI stability value (ASV), and yield stability index (YSI) all showed that SER-125, SER-119, and Rore were the most stable varieties across locations. **Conclusion:** As a result, SER-125 and Rore varieties should be recommended for the study areas and related agroecologies via pre-extension and demonstration.

KEYWORDS

Common bean, additive main effect, multiplicative interaction, AMMI stability yield stability index

INTRODUCTION

Common bean is one of the lowland pulse crops produced in the hot humid regions of Ethiopia. Common bean provides market value and strong nutritional composition, with high protein content in dry seed and a good source of fiber in snap bean[1]. It also has beneficial characteristics that can help control diabetes and certain cardiac disorders and is a natural remedy for bladder burn. It offers essential elements such as proteins, vitamins, and minerals to the diets of the resource poor[2]. It is widely planted in low and mid-altitude areas. It has many adaptations and thrives between 1300-2200 m above sea level at midland with an evenly distributed average rainfall of 1000 to 1200 mm during the growing[3]. Yield is unstable

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because it is controlled by polygenic genes and is heavily influenced by environmental changes[4]. As a result, the performance of different kinds differs depending on the area. Identification of varieties with particular, as well as broad adaptability is critical for enhancing the yield of tiny common bean varieties. Based on the foregoing, it is clear that the yield stability of common beans under various climatic and soil conditions is a critical characteristic of a sustainable farming system. The current study aimed to identify high-yielding, well-adapted, and stable small-seed type common bean cultivars suitable for various environments and to identify appropriate locations for growing small-seed common beans.

MATERIALS AND METHODS

Study area: The experiment was conducted in the Central Ethiopia Region, Abeshge, Mareko, and Sankura Districts of the Central Ethiopia Region for two consecutive cropping seasons (2020-2021).

Experimental design: Eight small-seeded common bean varieties were used in this experiment. Those are Awash-1, Awash-2, Awash-meten, Hawassa-dume, Nasir, Rore, and SER-119 and SER-125. Those varieties are collected from the Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Centre. A randomized complete block design with three replications was used. The plot size for the experiment was 2×1.6 m = 3.2 m^2, while the harvested area was 2×0.8 m = 1.6 m^2. The space between the row and the plant was 40 and 10 cm, respectively. Primary branches per plant, seeds per plant, seeds per pod, and pods per plant were gathered. Plant height, seed weight, and yield were all measured. The description of the study site was given in Table 1.

Data analysis of ANOVA and stability parameters: Analysis of variance type 3 with significance level at $p\leq0.05$ and $p\leq0.01\%$) mean performance of the treatment, and interactions with environment data were analyzed using R Software version 3.4. Least significant difference (LSD = 0.05%) used to mean separation of the treatments.

AMMI stability value (ASV): The AMMI Stability Value (ASV) was quantified based on the formula suggested by Purchase *et al.*[5] used:

$$ASV = \sqrt{\left(\left(\frac{IPCA1ss}{IPCA2ss}\right)(IPCA1)\right)^2 + (IPCA2)^2}$$

Where:

IPCA1ss = Interaction principal component axes 1 sum square

IPCA2ss = Interaction principal component axes 2 sum square

Yield stability index (YSI): The yield Stability Index (YSI) approaches incorporate both mean yield and stability and are calculated by using the formula suggested by Farshadfar *et al.*[6]:

$$YSI = RASV+RY$$

Where:

RASV = Ranks of AMMI stability value

RY = Rank of mean yield across environments

Table 1: Description of the experimental sites

Region	Woreda	Altitude m.a.s.l	Latitudes	Longitudes
Central Ethiopia	Sankura	1864	7°28'00"N	038°02'30"E
Central Ethiopia	Abeshge	1650	8°15'46"N	37°38'45"E
Central Ethiopia	Mareko	1834	7°05'67"N	038°18'18"E

m.a.s.l: Meter above sea level

RESULTS AND DISCUSSION

Analysis of Variance (ANOVA): Analysis of variance across locations (Table 2) revealed that there is highly significant variation across variety-by-location interaction. This indicated that there is the possibility of varieties performing at specific and/or wide adaptability for the testing region. The analysis of variance for each location (Table 3) indicated seed weight and yield had highly significant variation among those small-seeded common bean varieties in all studied districts. On the other hand, pod per plant and seed per plant at Sankura and Abeshge, seed per pod at Sankura and Mareko, primary branches per plant at Abeshge, and plant height at Sankura showed substantial variation among these small-seeded common bean varieties. Murut *et al.*[7], Awan *et al.*[8] and Elias *et al.*[9] found significant variance among common bean genotypes in seeds per pod and pods per plant. Similar to this, Daemo[10] also reported significant variation among common bean varieties for plant height, pod per plant, seed per pod, seed weight, and yield.

Mean performance of small-seeded common bean varieties: The SER-125, Rore, and SER-119 varieties had the highest mean yields throughout the investigated conditions. This indicated that varieties were performed and adapted at tested and similar agro-ecology areas. Sankura and Mareko environments showed the highest mean yield performance among those small-seeded common bean varieties. This indicated that those environments have a high potential for common bean production. The Abeshge site was a relatively lower-yielding environment as compared to other tested areas. The SER-125, Rore, and SER-119 varieties outperformed the grand mean in terms of yield, while the Awash-2, Awash-meten, and Awash-1 varieties underperformed the varieties (Table 4). The 1323-3546 kg/ha yield reported among common bean varieties, SER-119 and SER-125, were the highest-yielding varieties[10]. The maximum seed output and hundred seed weight were measured for the SER-125 variety, which was 2310.43 kg/ha at Abeshge, 2926.87 kg/ha at Sankura, and 3400.60 kg/ha at Mareko districts. The Awash-2 variety had the lowest yield at Abeshge (490.38 kg/ha) and Mareko (1299.79 kg/ha), whereas the Awash meten variety at Sankura District had the lowest yield measured by variety (Table 5).

Table 2: Analysis of variances for yields of small-seeded common bean across location varieties

Source of variation	Degree of freedom	Mean square value
Varieties	7	5626824**
Environments	5	8277003 **
Varieties by environment interaction	35	351466**
Environments: Replication	12	24677
Residual	84	20702

*Significant at p≤0.05, and **Highly significant at p≤0.01

Table 3: Analysis of variances for yields of small seeded common bean at the districts

SV	DF	PH (cm)	PP (No.)	SEP (No.)	HSW (g)	GY (kg/ha)	SP (No.)	BR (No.)
Sankura								
Variety	7	351.9**	245.32***	568	57.15***	1748518***	1.88**	0.80
Variety: Year	7	43.5	8.71	331	0.26	35685	0.13	0.54
Residuals	28	102.1	19.48	268	0.53	26009	0.52	0.60
Abeshge								
Variety	7	139.47	25.51***	834.4***	302.78***	2085519***	2.78***	2.36**
Variety: Year	7	99.40	0.69	49.8	12.61	24481	0.07	0.33
Residuals	28	82.59	0.80	66.8	0.57	9439	0.19	0.51
Mareko								
Variety	7	155.0	52.18	1002	42.83***	3473992***	2.60**	
Variety: Year	7	134.3	45.59	570	0.33	15959	0.12	
Residuals	28	80.0	28.18	610	0.6	26658	0.57	

**Significant variation at ≤0.01, ***Significant variation at p≤0.001, SV: Sources of variation, DF: Degree of freedom, PH: Plant height, SEP: Seed per plant, PP: Pod per plant, HSW: Hundred seed weight, SP: Seed per pod, BR: Primary branches per plant and GY: Grain yield per hectare

Table 4: Yield performances of small seeded common bean varieties across environments and varieties in kg/ha

	Environments						
Varieties	Abeshge-2020	Abeshge-2021	Mareko-2020	Mareko-2020	Sankura-2020	Sankura-2021	Variety mean
Awash-1	907.90	918.33	2381.50	2060.42	2131.80	2842.43	1873.73
Awash-2	480.77	500.00	1294.37	1305.21	1676.77	2235.70	1248.80
Awash Meten	857.43	885.33	1674.77	1584.38	1084.63	1446.17	1255.45
Hawassa Dume	976.00	1033.33	2474.73	2339.58	2359.13	3145.53	2054.72
Nasir	1626.60	1633.33	1999.17	1855.21	2288.87	3051.83	2075.84
Rore	1762.13	1430.00	3152.27	2921.88	2212.40	2949.93	2404.77
SER-119	1668.77	1681.00	3194.80	3138.54	1844.97	2459.93	2331.34
SER-125	2287.53	2333.33	3488.70	3312.50	2508.77	3344.97	2879.30
Environment mean	1320.89	1301.83	2457.54	2314.72	2013.42	2684.56	
Grand mean							2015.49

HSW: Hundred seed weight, GY: Grain yield, PH: Plant height, PP: Pod per plant, SEP: Seed per plant, SP: Seed per pod and BR: Primary branch per plant

Table 5: Yield and agronomic traits mean performances of small seeded common bean varieties at the districts

	Mareko			Sankura					Abeshge					
Varieties	HSW (g)	GY (kg/ha)	SP (No.)	PH (cm)	PP (No.)	HSW (g)	SP (No.)	GY (kg/ha)	PP (No.)	SEP (No.)	HSW (g)	GY (kg/ha)	BR (No.)	SP (No.)
Awash-1	22.82^{cd}	2220.96^{c}	4.93^{a}	78.00^{cd}	36.43^{a}	16.68^{c}	4.75^{ab}	2487.12^{c}	14.03^{cd}	39.17^{de}	15.02^{ef}	913.12^{cd}	5.57^{bc}	2.83^{cde}
Awash-2	18.77^{e}	1299.79^{f}	3.95^{bc}	78.00^{cd}	24.07^{bc}	16.18^{cd}	4.03^{bcd}	1956.23^{e}	14.50^{c}	58.22^{ab}	14.52^{f}	490.38^{e}	5.30^{bc}	4.15^{a}
Awash-Meten	17.25^{f}	1629.57^{e}	4.58^{ab}	92.40^{a}	19.97^{cd}	15.73^{d}	4.42^{abc}	1265.40^{f}	19.30^{a}	44.37^{cd}	15.43^{e}	871.38^{d}	5.17^{c}	2.55^{e}
Hawassa-Dume	24.50^{ab}	2407.16^{c}	3.52^{c}	71.83^{d}	19.57^{cd}	22.48^{a}	3.43^{d}	2752.33^{ab}	13.27^{de}	40.90^{d}	26.50^{c}	1004.67^{c}	6.90^{a}	3.27^{bc}
Nasir	22.33^{d}	1927.19^{d}	4.88^{a}	91.20^{ab}	25.60^{b}	19.75^{b}	4.55^{abc}	2670.35^{bc}	15.93^{b}	66.07^{a}	29.07^{b}	1629.97^{b}	6.10^{ab}	4.43^{a}
Rore	22.95^{cd}	3037.07^{b}	5.28^{a}	84.43^{a-c}	17.23^{d}	22.58^{a}	4.97^{a}	2581.17^{bc}	12.63 ^{e}	29.67^{e}	22.62^{d}	1596.07^{b}	5.32^{bc}	3.07^{cd}
SER-119	23.58^{bc}	3166.67^{b}	5.25^{a}	79.80^{b-d}	18.33^{d}	22.08^{a}	5.00^{a}	2152.45^{d}	14.27^{cd}	38.78^{de}	30.65^{a}	1674.88^{b}	4.93^{c}	2.73^{de}
SER-125	24.57^{a}	3400.60^{a}	3.98^{bc}	73.17^{cd}	18.03^{d}	22.48^{a}	3.85^{cd}	2926.87^{a}	14.33^{c}	51.23^{bc}	30.25^{a}	2310.43^{a}	5.72^{bc}	3.58^{b}
LSD 0.05	0.92	193.10	0.89	11.95	5.22	0.86	0.86	190.73	1.06	9.66	0.89	114.90	0.84	0.51

Small alphabets: Significant difference among two varieties (similar alphabet indicated non-significant difference among the varieties), HSW: Hundred seed weight, GY: Grain Yield, PH: Plant height, PP: Pod per plant, SEP: Seed per plant, SP: Seed per pod and BR: Primary branch per plant

Table 6: AMMI analysis for yield of small seeded common bean varieties at six environments

Sources of variation	Degree of freedom	Sum square	Mean square	Proportion	Accumulated	Treatment sum square (%)
Treatments	47	93074098				
Variety	7	39387767	5626824.0***			42.32
Environments	5	41385017	8277003.0***			44.46
Variety: Environments	35	12301314	351466.0***			13.22
Principal component 1	11	2843673.4	258515.8***	69.4	69.4	
Principal component 2	9	1106437.9	122937.5***	27.0	96.4	
Residuals	84	1738963	20702.0			

*Significant at $p \leq 0.05$, **Highly significant at $p \leq 0.01$ and ***Very highly significant at $p \leq 0.001$

AMMI stability analysis: The mean squares for variety, environment, and the variety-by-environment interaction for yield were all extremely significant. The primary effects of variety, environment, and environment-by-varietal interaction account for 42.3, 44.5, and 13.2% of variance, respectively. Principal component analysis was used to divide the interaction between environment and variety. Two major components (PCA1 and PCA2) were created. PCA1 and PCA2 exhibited considerable variation ($p \leq 0.001$), accounting for 69.4 and 27% of total environmental variation, respectively. The magnitude of PCA1 and PCA2 accounts for 96.4% of the interaction of the total variations, (Table 6) which is adequate to forecast variations for specificity as well as wide adaptability[6].

AMMI stability value (ASV): The AMMI stability value (Table 7) is significant for quantifying and ranking cultivars based on yield stability. The variety with the lowest AMMI stability value was identified as the most stable and vice versa[5]. Higher AMMI stability values were scored for the Rore, Awash-1, and SER-125 small-seeded varieties. This indicated that those varieties are more stable than other tested varieties. Similarly, the Rore and SER-125 varieties have a lower yield stability index than other varieties.

Table 7: Mean yield, AMMI stability values and yield stability index with their ranking orders of small common bean varieties

Varieties	AMMI stability value	Yield stability index	Ranks of AMMI stability value	Ranks of yield stability index	Means (kg/ha)
Awash-1	23.07	8.0	2	6	1873.73
Awash-2	37.37	14.0	6	8	1248.80
Awash Meten	26.50	11.0	4	7	1255.45
Hawassa Dume	29.91	10.0	5	5	2054.72
Nasir	38.96	11.0	7	4	2075.83
Rore	20.99	3.0	1	2	2404.77
SER-119	52.14	11.0	8	3	2331.33
SER-125	25.77	4.0	3	1	2879.30

Yield stability index (YSI): The yield stability index helps identify high yielders with the best stability in a single criterion. A low yield stability index value combined with a high mean yield suggested that the variety was more stable across the studied districts. The present study indicated that the SER-125 and Awash-1 varieties are stable across environments. In addition to this, SER-125 was the high-yielding variety across locations. Tola *et al.*[11] researched common beans and reported that genotypes with high yielders broadly adapted to wide environments.

CONCLUSION

There were significant variances in yield and hundred seed weight across all test locations. The variety-environment interaction was also important for yield, demonstrating that the performance of varieties for yield varied by location, allowing for the selection of stable as well as specific adaptable varieties. SER-125, Rore, and SER-119 exceeded the grand mean. According to the AMMI analysis, the AMMI stability value and yield stability index indicated that SER-125 and Rore were stable and outstanding kinds. SER-125 and Rore varieties should be demonstrated in the tested and similar agro-ecologies. In addition to those, the Hawassa Dume variety also performs best in the Sankura district and should be exhibited using pre-extension and demonstration protocol.

SIGNIFICANCE STATEMENT

Low production of common beans is a serious issue in the Central Ethiopia Region due to limited utilization of improved varieties. The evaluation of raised common bean varieties with specific or general recommendations might boost the production and productivity of these beans. According to this study, the SER-125 and Rore cultivars had higher yields and were stable. In addition to these kinds, the Hawassa-Dume variety performed well in Sankura Region. Demonstrating these cultivars in tested and similar agroecology settings will boost common bean yield and productivity.

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