



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2021; 4(2): 50-54

Received: 15-05-2021

Accepted: 18-06-2021

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Evaluation of improved common bean (*Phaseolus vulgaris L.*) Varieties for yield and yield components at West Hararghe, Eastern Ethiopia

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Abstract

Common bean is playing a crucial role across the world mainly in the warm and lowland areas of the country including Ethiopia. Understanding the level of drought tolerance of the varieties available in each country is of paramount importance for breeding common bean for drought adaptation. However, the production of common bean is mainly limited due to lack of high yielding potential varieties and frequent and recurrent drought. Hence, the study was aimed to evaluate and identify the superior performance and genetic potential of improved common bean varieties for yield and yield related traits against drought. A total of 10 recently released improved common bean varieties were evaluated using a randomized complete block design (RCBD) with three replications at Mieso during the main cropping season of 2018 and 2019. The information generated on the drought tolerance of the available varieties should help in the design of a breeding strategy that incorporates adaptation traits with commercial characteristics preferred by common bean farmers for varieties to be grown in diverse environments. The combined analyses of variance revealed the presence of tremendous genetic variation among improved common bean varieties for all the studied traits except plant height and stand count at harvest, which implies the availability of substantial genetic variation among varieties. Overall, SER-125, SER-19 and Nasir common bean varieties had better performance compared to the other varieties for yield and the yield related traits. The maximum grain yield was obtained from SER-125 (2620 kg ha^{-1}) followed SER-19 (2612 kg ha^{-1}) and Nasir (2583.33 kg ha^{-1}) common bean varieties and identified as the superior improved common bean varieties. Eventually, the effect of varieties on grain yield was significant and the best performing varieties of common bean would be recommended for the specific community and its vicinity even though further study should be carried out including a number of recently released varieties for improved common bean production in the target area and also to put the recommendation on strong basis. Therefore, based on the results of this adaptation experiment, SER-125, SER-19 and Nasir were recommended for production and adoption at Mieso and other similar environments.

Keywords: *Phaseolus vulgaris*, yield, yield components, performance, drought stress, yield stability

1. Introduction

Common bean (*Phaseolus vulgaris* L. $2n = 2x = 22$) is one of the principal food legume in the world and is the most important source of dietary protein in Africa (Mercati *et al.*, 2013) [20]. Common bean is an annual crop which belongs to the family Fabaceae. It grows best in warm climate at temperature of 18°C to 24°C (Assefa, T *et al.*, 2015) [5]. Common bean is the most widely distributed *Phaseolus* species as it is grown across all the continents with a broad range of adaptation to various environmental conditions (Porch *et al.*, 2013) [25]. Population genetic analyses revealed that wild common bean consists of two geographically isolated and genetically differentiated gene pools, Mesoamerican and Andean, which diverged about 100,000 years ago (Mamidi *et al.*, 2013) [18]. The cultivated common bean was domesticated from the two gene pools independently about 8000 years ago and then underwent local adaptation that has led to distinct phenotypic characteristics among different cultivars (Bitocchi *et al.*, 2013) [7]. There are many pulse species are grown in Ethiopia. Of these, Faba bean, field pea, chickpea, lentil, grass pea, fenu greek and lupine are categorized as highland pulses and grown in the cooler highlands. On the contrary, common bean, soya bean, cowpea, pigeon pea and mung beans are principally grown in the warmer and low land parts of the country. Among the individual varieties, faba beans (broadly known as horse beans) accounts for the maximum fraction of production, at 36%, followed by common beans (17%) and chickpeas (16%). Other pulses (lentils, peas, lupines and mung beans) account for the remaining 32% (Yirga, C *et al.*, 2019) [32].

The global production of common bean is nearly 12 million tons per annum. The East and Southern Africa regions produces about 2.5 million tons per annum (Petry, N *et al.*, 2015) ^[24]. Approximately 40 per cent of Africa's production is marketed for about 450 million US dollars (Katungi, E *et al.*, 2009) ^[13], and small holder farmers account for the bulk of the cultivated crop. Common bean contributes to the national economy as both a food and an export commodity, in both cases serving as a source of income and employment to a large supply chain (Tumsa, K *et al.*, 2014) ^[30]. The crop provides vital nutrients as a food including vitamins, proteins, and minerals and the stems are also used as fodder for livestock, especially in the dry spell following the main cropping season (Wondatir, Z and Mekasha, Y, 2014) ^[31].

Common bean is a major grain legume which is consumed worldwide for its edible seeds and pods. It is the third most important source of calories after maize and cassava, serving millions of low-income households (Alemu H, 2017) ^[1]. Common bean is one of the most important legume crops, providing as much as 15% of total daily calories and 36% of total daily protein in parts of Africa and the America (Schmutz *et al.*, 2014) ^[27]. According to Miklas *et al.* (2006) ^[22], this crop has a high nutritional value with important protein contents (~22%), minerals (calcium, copper, iron, magnesium, manganese, zinc) and vitamins necessary to warrant the food security of people in the developing countries. Common bean is a traditional crop of the neo-tropics, where it was domesticated several thousand years ago (Teran, H. and Singh, S.P., 2002). The East African highlands are a region of important common bean production and high varietal diversity for the crop (Shabib, J.M *et al.*, 2013) ^[28]. Common bean is a legume commonly grown in sub-Saharan Africa for food, cash, animals' food, and as soil improver (McConnell M *et al.*, 2013) ^[19]. Beans are often considered as the "poor man's meat" and consumed as seeds (mature or immature) as well as a vegetable (both leaves and pods) (Høgh-Jensen H *et al.*, 2013) ^[12]. Common bean is one of the most important legumes and is high in protein, low in fat, and rich in vitamins and dietary fiber (Beebe *et al.*, 2013) ^[6]. The regular consumption of common bean can reduce coronary heart disease, type II diabetes, and cancer (Krupa, 2008) ^[14].

Common bean is very favored by Ethiopian farmers because of its fast maturing uniqueness that enables households to get cash returns essential to pay for food and other household needs when other crops have not yet matured (Legesse *et al.*, 2013) ^[15]. The major producing regions are Oromia (mainly East Shewa, East and West Hararghe, West Arsi, and Arsi zones) and SNNPR (Gerezihier *et al.*, 2017) ^[10]. According to CSA, (2019) ^[9], common bean takes 12.73 % of the total area coverage (1,620,497.30 hectares) and 9.54% (about 30,113,480.57 quintals) of the produced grain in Ethiopia. Ethiopia had got 85% of export estimated earnings from pulses, exceeding that of other pulses such as lentils, faba bean and chickpea (Merga, J.T, 2020) ^[21]. According to Amsalu, B *et al.*, (2018) ^[2], Ethiopia exported 14 % (340,000 metric tons) of pulse production and generated \$ 255 million US dollars. Common bean can be produced either as sole crop or intercrop with cereals like maize and sorghum. This helps not only securing yield but also has the advantages of restoring soil fertility. Even though, the country has huge potential and the crop has tremendous advantages, the production and productivity has been challenging by low adoption of improved technologies, drought, and lack of improved varieties, poor cultural practices, disease, and environmental degradation (Merga, J.T, 2020) ^[21].

The crop is cultivated in several agro-ecological zones and farming systems and mainly grown by small-scale farmers for

household consumption, marketing and soil fertility improvement purposes (Asfaw *et al.*, 2012) ^[4]. Ethiopian farmers have a higher preference to grow common beans, compared to other legumes, because they mature early, which helps them to obtain a cash income to buy food and other household needs. It also serves as an emergency crop in times of crop failure (Legesse *et al.*, 2013) ^[15]. The common bean was introduced to Ethiopia in the sixteenth century and farmers have been able to adapt, develop and maintain a large genetic diversity to suit their needs. The conventional plant breeding scheme uses a narrow range of selection criteria that addresses issues related to yield, uniformity and stability. Traditional farmers, however, employ more diverse and complex selection criteria, revolving around stable crop performance over seasons and they grow a range of genotypes that meet their needs in very complex and heterogeneous environments (Ceccarelli and Grando, 2007) ^[8]. Breeding for drought-tolerant crops is challenging and time-consuming, owing to the need for simultaneously considering multiple abiotic and biotic factors modulating the level of drought-tolerance. Previous attempts made to evaluate genotypes for drought tolerance indicated high levels of drought tolerance in Durango landraces and some Mesoamerican common bean cultivars (Beebe *et al.*, 2013) ^[6]. Genotypic evaluation studies in Ethiopia identified drought tolerant genotypes and selection traits for improving drought adaptation in common bean (Asfaw, A and Blair, M.W, 2014) ^[3].

In Ethiopia, the National Common Bean Research Program plays an important role in meeting the increasing demand for the crop by releasing improved common bean varieties. However, the common bean productivity is limited in Ethiopia and the average national yield of common bean in Ethiopia is estimated at 1300 kg ha⁻¹ on smallholder farms and 1700 kg ha⁻¹ on commercial farms (Livestock, C.S.A., 2017) in contrast to a production potential of 3000 to 4000 kg ha⁻¹ in research fields (Yirga, C *et al.*, 2019) ^[32]. Therefore, there is a large gap among the actual and potential yield of a crop; and hence this calls for research interventions. Constraints that cause common bean yields include lack of suitable varieties for farmer's needs, a biotic stresses (drought, low soil fertility) and biotic stresses like pests, diseases, poor agronomic practice and limited research work. Hence, more researches are required across different agro ecology zones to boost productivity. Therefore, there is a need to develop high yielding and stress-tolerant cultivars to improve productivity.

The successful development and deployment of improved cultivars depend upon available genetic diversity and appropriate breeding strategies. The lack of the improved varieties of common bean is the major problem that plays a great role for the lower yield of the common bean (Mitiku, M and Mesera, T, 2017) ^[23]. Therefore, there is need to introduce the improved common bean varieties to the target area is paramount important to come up with improved productivity and production of common bean in the study area. Therefore, the study was conducted with the objectives to evaluate and recommend high yielding and early maturing common bean varieties in the moisture stressed areas of west Hararghe and other similar environments.

2. Materials and Methods

2.1 Description of the Experimental Location

The field experiment I was conducted under rain-fed conditions at Mieso Agricultural Sub- Research station during the 2018 and 2019 main cropping seasons. Mieso is located 302 kilometers away in the eastern from Addis Ababa, the capital city of

Ethiopia in Oromia regional state. Its elevation is 1470 metres above sea level and is located at 8°30'N latitude and 39°21'E longitudes and with having an average maximum and minimum temperatures of 14.0°C and 30.01°C and with an average annual rainfall 763mm. The dominant soil type is Vertisols with pH 5.4 (Lemma, 2008) [16].

2.2 Plant Materials

A total of 10 recently released improved common bean varieties were evaluated for yield and yield related characters. The improved lowland common bean varieties were released for lowland agro-ecologies by the national lowland pulse improvement program in different times. These materials were evaluated and released for the pros of well adaptive and stability of yield, earliness in terms of maturity, resistance to diseases, seed size and color, biomass and other quality characteristics.

Table 1: Description of the experimental materials

S. No	Variety	Agro-ecology	Status	Source
1	SER-125	Lowland	Released Variety	Melkasa ARC
2	SER-119	Lowland	Released Variety	Melkasa ARC
3	Nasir	Lowland	Released Variety	Melkasa ARC
4	KAT B-9	Lowland	Released Variety	Melkasa ARC
5	BZ -2	Lowland	Released Variety	Melkasa ARC
6	Awash Melka	Lowland	Released Variety	Melkasa ARC
7	KAT B-1	Lowland	Released Variety	Melkasa ARC
8	Awash -2	Lowland	Released Variety	Melkasa ARC
9	Damee	Lowland	Released Variety	Melkasa ARC
10	Awash -1	Lowland	Released Variety	Melkasa ARC

2.3 Experimental Design and Trial Management

The experiment was arranged in a completely randomized block design with two replications during 2019 main cropping seasons to evaluate the varieties. The plot size was 4 x 2.4 m (9.6 m²) having 4 rows with harvestable plot size of 1.6 x 4 m (6.4 m²) and a spacing of 0.40 m between rows and 0.10 m between plants was maintained. The spacing between replication, blocks and plots within each block was 1.50, 1 and 0.50 m, respectively. All the standard agronomic packages and fertilizer rates of 100 kg ha⁻¹ DAP was applied at the time of planting whereas 100 kg ha⁻¹ Urea fertilizer was set aside homogeneous for all treatments and urea was applied in split three times. Weeds were controlled periodically by hand weeding and other management practices like pest or disease-control was done as required.

2.4 Data Collection

Physiological traits of genotypes were assessed by measurement of multiple plant attributes using nondestructive sampling at different growth stages of the crop. The traits measured were: Days to flowering was recorded as the number of days from emergence to when 50% of the plants had flowered in a plot, days to maturity based on number of days from sowing to physiological maturity of at least 90% of the plants in a plot, ground cover was counted on a plot before harvesting the pods, stand count at harvest was counted on a plot before harvesting the pods, plant height was also measured at mid pod filling stage on five plants per plot using meter stick grain yield was recorded from the four central rows of each plot.

2.5 Statistical Analysis

A general linear model (GLM) was used for data analysis and LSD at $P \leq 0.05$ was used for mean separation. The data were analyzed using PROC ANOVA in SAS software version 9.4

(SAS, 2018) and means were separated using Fisher's Least Significant Difference (LSD) test at 5% level of probability as stated in Gomez and Gomez (1984) [11].

3. Result and Discussion

3.1 Analysis of Variance for Yield and Yield Related Traits

The analyses of variance (ANOVA) for all quantitative traits showed the presence of very and highly significant difference at different probability level among the common bean varieties for yield and yield related characteristics (Table-2). The combined analysis of variance exhibited very highly significant difference at 0.1% probability level in common bean varieties for grain yield (kg) and ground cover and highly significant difference observed for (days to 50% flowering and Days to 90% maturity at 1% probability level. This indicated the presence of considerable variation in the genetic materials for these traits and there is a possibility to improve the investigated common bean varieties with simple selection. Plant breeding is primarily depending on presence of substantial genetic variation to address the maximum genetic yield potential of the crops and simple selection can be effective to make further improvement when the genetic variation is available among the studied varieties. Presence of significant difference among common bean varieties for the studied traits ensured the presence of substantial genetic variation to be improved through selection. Hence, the obtained results encourage the presence of substantial genetic variation among varieties for the studied traits for further selection. With regards to the present experiment, the existence of genotypic variation in grain yield and yield components has been played a crucial role for common bean improvement.

Table 2: Combined analysis of variance of cowpea varieties for yield and yield related traits

Source of Variation	DTF	DTM	GC	SH	PHT	GY
Replication	5.033	21.43*	0.900	415.97 ^{ns}	32.5 ^{ns}	67290
Genotypes	30.889**	21.86**	3.41***	746.23 ^{ns}	42.96 ^{ns}	143460***
Error	8.2556	5.8778	0.5667	1017.3	51.01	413352

***Very highly significant at 0.1% probability level, **highly significant at 1% probability level, *highly significant at 5% probability, ns = non-significant at 5% probability level where, DTF=days to 50% flowering, DTM=days 90% to physiological maturity, GC =ground cover, SH=stand count at harvest, PHT=plant height, GY=grain yield.

3.2 Mean Performance of cowpea Genotypes for Yield and Yield Related Traits

The superior common bean varieties were identified based on the mean performance for different characteristics as indicated in (Table-3). The combined means result indicated that the SER-125 (2620 kg ha⁻¹), SER-19 (2612 kg ha⁻¹) and Nasir (2583.33 kg ha⁻¹) common bean varieties had the highest yield respectively. This showed the improved lowland common bean varieties had better adaptation and yield advantages at moisture stressed areas. The higher mean performance of varieties for yield under drought stress conditions suggests that common bean responds to drought stress by increasing root growth. BZ-2 variety flowered (43 days) and matured (59 days) and KAT-9 variety flowered (43 days) and matured (59 days) earlier. Significant reduction in days to flowering and days to physiological maturity as a result of drought stress was observed in the present study. Days to flowering and maturity are among the most important characteristics that need to be considered in selecting varieties when and where the shortage of rainfall is

limiting factor for further improvement of yield and yield related traits. However, early maturing varieties have been shown low yield whereas the late mature varieties have shown high yield. Hence, the yield performance the varieties were not directly correlated to improve though simple selection and suggested to search for another breeding procedures to improve the yield and maturity of varieties for drought tolerance.

The earliness trait (days to flowering and days to physiological maturity) enables them to flower and mature early, therefore escaping from moisture stress, the most important drought factors that results in reduced yield. Nowadays, the development of the superior varieties in terms of yield and other many different traits very critical to address the required challenges of human population growth and climate change. Overcoming these difficult challenges will be harder in the absence of plant genetic improvement to increase agricultural productivity through addressing the problem of yield reduction and its links with pest management and climate change. Based on the mean performance, the superior common bean varieties were identified for different traits as indicated in (Table-3). Interestingly, the maximum grain yield was obtained from SER-125 (2620 kg ha^{-1}) followed by SER-19 (2612 kg ha^{-1}) and Nasir

(2583.33 kg ha^{-1}) common bean varieties.

Table 3: Mean values of different Common bean varieties for grain yield and other agronomic characters

Varieties	DTF	DTM	GC	SH	PHT	GY
SER-125	48.00ab	62.00bc	2.67cd	130.33a	34.35a	2620.00a
SER-19	49.67ab	63.67abc	2.33c	128.33a	33.33a	2612.00a
Nasir	52.67a	69.33a	2.00b	127.67a	32.33a	2583.33a
KAT-9	43.00c	59.67c	4.33de	104.33a	30.33a	2095.00ab
BZ-2	42.67c	59.67c	3.00cd	119.63a	29.96a	1998.33bc
Awash Melka	48.33ab	66.00ab	2.67cd	130.33a	29.67a	1987.33bc
KAT-1	46.00bc	59.67c	5.00e	101.00a	29.33a	1537.00cd
Awash-2	49.67ab	63.27abc	2.00b	138.67a	28.36a	1525.00cd
Damee	46.33bc	64.67ab	1.67a	96.33a	26.32a	1213.33d
Awash-1	50.67a	64.00ab	3.33bcd	99.00a	25.33a	1031.33d
CV %	6.03	3.84	25.96	27.13	29.23	16.72
LSD 0.05	4.93	4.16	1.29	54.71	10.55	550.87

Note: Means in a column with the same letter (s) are not significantly different by LSD's test (P=0.05), DTF=days to 50% flowering, DTM=days to physiological maturity, GC=ground cover, SH=stand count at harvest, PHT=plant height, GY=grain yield, LSD=Least significance difference, CV (%) = Coefficient of variation in percent.

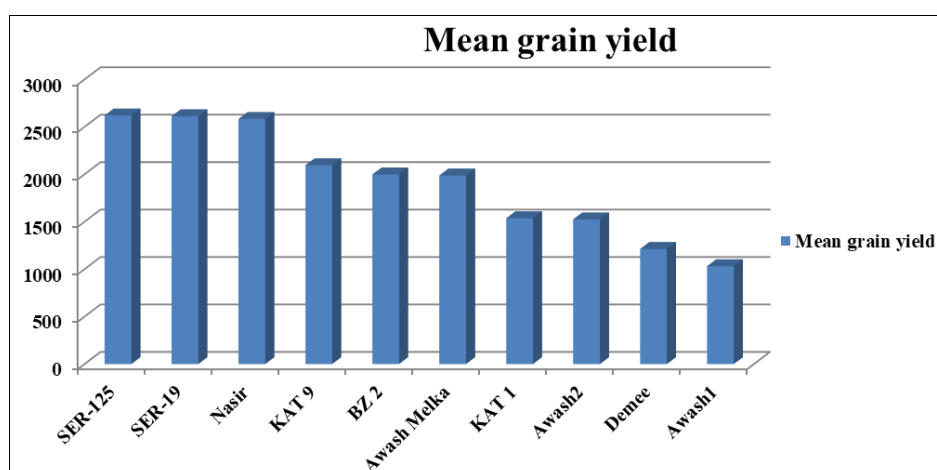


Fig 1: The mean yield performance of common bean varieties in study area

4. Conclusion

Common bean is one of Africa's most essential pulses. The adaptation of common bean varieties to drought-stress conditions is very crucial for drought prone areas particularly lowland parts of Ethiopia. Drought stress linked with climate change is one of the major constraints faced by common bean farmers in Africa and elsewhere. Mitigating this constraint requires the selection of resilient varieties that withstand drought threats to common bean production. The crop provides vital nutrients as a food including vitamins, proteins, and 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. Most common bean production in the developing world occurs under conditions where the risk of drought is high.

The present investigation revealed 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. The presence of considerable variation in the genetic materials implied that the possibility to improve the genotypes with simple selection for the studied traits. 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. This significant genetic variation among genotypes suggested that the varieties were genetically diverse and it could be a good opportunity for breeders to select genotypes for trait of interest for variety development.

Hence, the obtained results encourage the availabilities of substantial genetic variation among varieties for the major studied traits. The potential common bean varieties identified based on the superior mean yield performance and other related traits. Analysis of variance showed highly significant varietal differences days to 50% flowering and Days to 90% maturity at 1% probability level and very highly significant difference observed for grain yield and ground cover at 0.1% probability level. The combined means result indicated that the SER-125 (2620 kg ha^{-1}) and SER-19 (2612 kg ha^{-1}) common bean varieties had the highest yield respectively. The earliness trait (days to flowering and days to physiological maturity) enables them to flower and mature early, therefore escaping from moisture stress, the most important drought factors that results in reduced yield. Most of the varieties showed adaptation to drought stress by reducing their days to physiological maturity, thereby minimizing the effect of drought. As compared to the others, SER-125 and SER-19 common bean varieties were recommended as promising varieties to the farmers of Mieso

area and other districts having the same agro-ecologies based on their optimal yield performance for further adoption.

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