Unlocking the Potential of Common Bean (*Phaseolus vulgaris* L.): A Key Ingredient for Smallholder Farmers' Livelihood and Income Generation

Abstract

Common bean is the most important legume crop in Ethiopia. However, several production constraints including poor agronomic practices remain challenges to enhance the yield and utilisation. With this scenario, the experiment was conducted to evaluate five improved common bean varieties and select the best stable performance through farmer's participation in Sire district. For this, twelve farmers were chosen and used as replicates to reach proper inference. Results from analysis and farmers evaluation revealed that SER-119 variety was selected for its high return and agronomic performance. The study further showed, farmers could obtain on average 119,222.20 ETB per hectare by producing improved varieties. However, farmers obtained a maximum benefit by using SER-119 variety. The sensitivity analysis showed that the most influential factor on a farmer's profit is the yield and market price. Similarly, the benefit cost ratio (BRC) of 1.57 showing the enterprise is profitable in the study area. Therefore, it is recommended to scale the farmers' preferred and profitable variety (SER-119) in common bean producing areas.

Keywords: farmer's preference, feasibility, participatory evaluation, sensitivity analysis

Introduction

Common bean (*Phaseolus vulgaris* L.) is the second important legume crop grown by smallholder farmers for food, animal feed and income in Ethiopia (CSA, 2019). It is a key source of dietary protein, carbohydrates and essential micronutrients iron and zinc (Tebeka et al., 2017). Common bean has a capacity to reduce malnutrition, thus considered as a nutrition security crop. It is also a prime export crop for earning foreign currency (Blair et al., 2010; Didinger et al., 2022).

Wide variation exists among common bean cultivars that can grow in diverse cropping systems and agro-ecologies (Kassa et al., 2019). Despite common bean multiple importances, crop yield is very low especially in the farmer's field compared to its potential in Ethiopia. According to Beebe et al. (2013), the national average common bean

yield is 1.6 t ha^{-1} which is far below at the research field yield of 4.0 t ha^{-1}. This is attributed mainly to various biotic and abiotic stresses (drought, soil infertility, diseases and insect pests) as well as the high dependency of farmers on local cultivars susceptible to these stresses. To maximize crop yield, the use of improved varieties combining with application of proper agronomic practices play key roles and have been reported to increase yield up to 27% (Fitsum et al, 2021). Understanding this, an experment on participatory evaluation of improved varieties of common bean in Sire district was implemented.

Materials and Methods

Site description

Participatory evaluation of common bean varieties was implemented in Sire district, which is located in Arsi zone, Oromia regional state of Ethiopia. The activity was carried out on twelve farmers during 2023 rainy season. The geographic locations of the experimental area are shown in Table 1 and the distribution pattern of experimental sites has been mapped (Figure 2). Testing farmers were selected considering their willingness to host the activity and proximity to road for ease inspection; and selection was done jointly with development agents (DAs) and agricultural experts of the district. The study area is characterized by sub-humid agro-ecology with a unimodal rainfall pattern and sandy soil texture. The minimum and maximum mean monthly temperature, rainfall received and the 32 years (1991 - 2022) mean monthly rainfall climatology are shown (Figure 1). July, the first month of planting accommodated the highest rainfall and relatively warm temperature (Figure 1).

Figure 1. Mean monthly temperature and rainfall distribution during 2023 main season

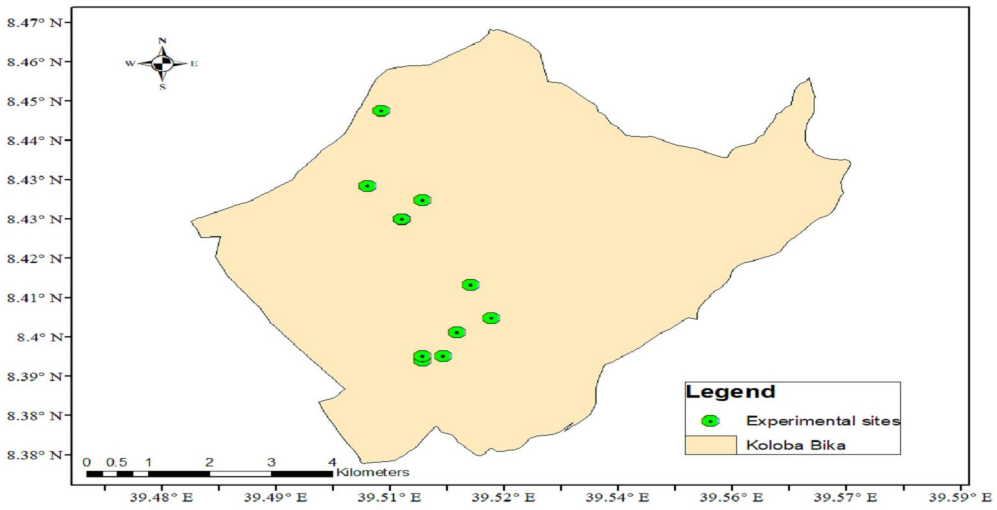

Figure 2. Distribution patterns of the experimental locations

Treatments, study design and managements

Five recently released improved common bean varieties were evaluated through a participatory approach to replace the highly susceptible and low yielding local varieties of farmers. SAB-632 and DAB-372 from speckled or sugar bean, SER-119 and SER-125 from red seed colour, and KAT-B1 from yellow colour (Table 2) were selected and evaluated using participatory approach on twelve farmers and one FTC. Randomized complete block design (RCBD) was used to lay down the varieties using farmers and FTC as replications. The experimental lands were prepared using oxen and row was made with hand tools. The seeds were planted between July 18 and July 21, at a rate of 100 kg/ha, with 40cm x 10cm (row x plant) spacing. DAP (Diammonium phosphate) at the rate of 100 kg/ha were applied during planting. All other remaining management practices were done as per the recommendation for common bean.

Table 1. Demonstrated and evaluated varieties characteristics

Varieties	Characteristics	
	Research field yield (kg/ha)	Seed colour

SAB-632	2400	Speckled
DAB-372	2300	Speckled
SER-119	3300	Red
SER-125	3500	Red
KAT-B1	2600	Yellow

Data collection

Both quantitative and qualitative data were collected for participatory evaluation activity. The type of data includes: (a) Plant height was taken from ten randomly selected plants measured in cm from the base of the plants to the top leave (b) Days to 50% flowering: counted as the number of days from sowing to when 50% of plants have at least one open flower (c) Days to physiological maturity: The number of days from planting to the stage when 90% of plants in a plot have reached physiological maturity (d) Hundred Seed weight (g): was determined by weighing the mass of 100 seeds and adjusted at 12.5% moisture basis (e) Number of pods per plant: the number of pods counted from ten randomly selected plants (f) Number of seeds per pod: the number of seeds counted from ten randomly selected plants within plot (g) Number of seeds per plant: determined by multiplying the number of pods per plant and number of seeds per pod (h) Grain yield (kg/plot): yield harvested from four central rows, measured using sensitive digital balance (Ranger 300), and corrected to measured seed moisture values using moisture meter (Dickey John Corporation, U.S.A) and finally adjusted at 12.5% seed moisture content using equation,

$$Y_{adj} = [() * Y]$$

Beside these, farmer preferred traits, data on inputs use, costs incurred, amount harvested and sold price were recorded.

Data analysis

Analysis of variance and descriptive analysis

To assess variation among varieties, analysis of variance (ANOVA) was employed using SAS version 9.2 (SAS institute, 2008) and GenStat version 18 (VCN international, 2015) statistical packages. Significant means were compared at 5% level of significance to

compare performance variation between varieties. Farmer's preference was assessed using pairwise-ranking methods. Finally, collected data were analyzed using descriptive statistics, preference ranking, and yield gap analysis techniques. Benefit-to-cost ratio was also calculated to assess the financial feasibility of improved common bean production.

Gross margin

Gross margin analysis was employed to better understand the relationship between sales revenue and cost structures and assess profitability of common bean production to enable informed decision making. Gross margin analysis was used to estimate the profitability of common beans production. The difference between revenue and total variable costs is the gross margin for the enterprise (Leslie, 2013).

Results and Discussions

Demographic features of target farmers

The demographic features of the farmers selected for participatory evaluation task are summarized (Table 2). The mean age of the households was 40 years, with relatively larger family size (7) and better land holding (3 ha). The year spent on education was 6 on average which suggests the low schooling year of the farming households. Majority of selected households for demonstration was male (63%) which was relatively two times greater than female (37%).

Table 2. Demographic features of target farmers

Descriptions	Mean	SD
Age (years)	40	9
Family size	7	4
Education level (years completed)	6	6
Farm size (ha)	3	2
Male demonstration host farmers (%)	63	
Women demonstration host farmers (%)	37	

Agronomic traits performance

Results from ANOVA revealed that evaluated common bean varieties were significantly differed ($p \leq 0.001$) in all measured traits including grain yield (Table 4) suggesting the presence of better performing varieties and increase the possibilities of selection. Wide variations were observed among common bean varieties in their mean performance ranged

from 43.85 to 49.23 cm for plant height, 82.54 to 85.46 for days to maturity, 13.25 to 16.45 for number of pod per plant, 6.76 to 9.45 for number of branches per plant and 2119.20 to 2338.80 kg for grain yield (Table 5). SAB-632 (49.23cm) gave the highest plant height whereas KAT-B1 was the shortest (43.85cm) though it was the shortest to mature took solely 82.54 days. Both SER-119 and SER-125 which are red in seed colour had the highest number of branches per plant, 9.45 and 9.01, respectively, as well as demonstrated the highest grain yield 2338.80, 2255.70, respectively. The lowest was grain recorded by KAT-B1 (2119.20), suggesting that short maturing variety had lower yield and positively correlated. Apart from this, low variations were detected among varieties for other traits including days to flowering, seed per pod and pod length. This significant variation indicates the presence of genetic variation between the common bean varieties and the attribute being studied. Genetic diversity is likely critical for crop future breeding programs which will rely on phenotypic and molecular characteristics of such genetic resources to generate new common bean varieties. Kassahun and Asmamaw (2021), and Gebre-Egziabher et al. (2014) found significant variation between common bean varieties for their yield and related trait performances. Firew et al., (2012) also found and reported a significant variation among the common bean varieties for their plant height and date of maturity.

Table 3. Mean square from analysis of variance for all measured agronomic traits

Source of variation	df	PH	DTF	DTM	PPP	SPP	PL	NBPP	GY
Variety	4	56.34 *	6.62^{ns}	14.73 **	25.33 *	0.77^{ns}	4.72^{ns}	15.12 **	100664 **
Replication	12	27.05	3.74	1.69	19.43	0.53	3.08	2.85	52058
Error	48	22.80	2.55	2.13	6.22	0.48	3.03	2.46	23504

** = Significant P≤0.01 probability level; df = degrees of freedom; Gen= Genotype; Rep= Replication; PH= Plant height; DTF = Days to flowering; DTM = Days to maturity; PL= Pod length; SPP=Seed per pod; PPP = Pod per plant; NBPP= Number of branches per plant; GY = Grain yield

Table 4: Mean performance of evaluated varieties for yield and other agronomic traits

Variety	Plant height (cm)	Flowering date	Maturity date	Pod per plant	Seed per pod	Pod length (cm)	No branches per plant	Grain yield (kg)
DAB-372	46.54a	39.92a	85.46a	13.25 a	5.38 a	11.77 a	7.62a	2288.30
KAT-B1	43.85	39.69a	82.54	13.85 a	4.81	10.73	6.76a	2119.20
SAB-632	49.23	40.54b	84.62a	14.29	5.37 a	12.16	8.16	2325.20
SER-119	47.31a	40.92b	84.23b	16.45 b	5.36 a	11.87 a	9.45a	2338.80
SER-125	48.46	40.77b	84.31b	16.03 b	5.25 a	11.04 a	9.02a	2255.70
Grand Mean	47.08	40.37	84.23	14.77	5.24	11.51	8.20	2265.44
LSD	3.77	1.26	1.15	1.97	0.55	1.37	1.24	120.91
CV	10.14	3.96	1.73	16.89	13.33	15.14	19.13	6.77

Means with the same letters in the same column are not significantly different at a 5% level of significance

Table 5: Grain yield of demonstrated varieties

Variety	Mean	Maximum	Minimum	SD
DAB-372	2288.33	2488.64	1781.47	181.57
KAT-B1	2119.15	2381.58	1781.25	186.91
SAB-632	2325.19	2607.14	2190.00	126.53
SER-119	2338.83	2578.43	1935.81	159.44
SER-125	2255.72	2737.50	1976.43	191.67

Table 5 revealed the yield potential of bean varieties compared to their potential at research field, as well as the experimental and farmers yield gaps. SAB-632 was the unique variety among others offered yield closest to its potential at research field which left merely 74.81 experimental yield gap. Though both SER-119 and SER-125 varieties gave the highest yield, their demonstrated yield were far apart from the research potential which left a wide experimental yield gap compared to SAB-632 and KAT-B1 varieties.

Farmers' feedback and ranking

Based on the farmer's response, cultivation of improved common bean varieties was very limited. Though the crop is grown in the rainy season, it is mostly cultivated as a sole crop on small plots mostly in infertile marginal land with low inputs and poor management practices. Common bean farmers predominantly grow common bean for household

consumption. Farmers in the Sire district cultivated mainly the locally available variety called 'Bora' which is larger in seed size but susceptible to diseases and insect pests as well as low in yield compared to the improved varieties developed by research institutions. Beside the measured agronomic traits, opportunities were also given to the farmers and households to evaluate the demonstrated varieties as well as to identify farmer's preferred varieties and their selection criterions. In addition to this, farmers were also asked the experience they have on common bean production in terms of age and year. Though they have long experience in bean production, lack of access to improved varieties, various biotic and abiotic stresses particularly drought, soil infertility, various bacterial and fungal diseases, lack of awareness in proper bean production and utilization, as well as poor management practices are among the major bean production constraints that undermine the crop yield potential and farmers utilization.

Farmers' traits preference

As part of evaluation, representative farmers were selected and grouped into focus group discussions (FGD). According to Ntare and Ndjeunga (2009), voting for the best and worst varieties by farmers can be associated with a high likelihood of varietal adoption and/or non-adoption. Within this scenario, the evaluation procedure was conducted two weeks prior to harvesting through focus group discussions. The list of preference criteria for the common bean was ranked using pair-wise ranking to identify the priority traits for farmers. The established criteria were used to rank the demonstrated varieties by the focus group discussants. First the farmers were asked to record the criteria used to select common bean varieties. Then they scored the demonstrated varieties for each of the criteria based on the frequency. The study found that environmental adaptability, disease resistance and yield permanence are important attributes for farmers' choice of common bean varieties (Table 7). This result shows the farmers trait preference for varieties selection is beyond yield which in lines findings reported by Fekadu (2013) that the farmers' selection criteria for common bean were beyond yield. Moreover, this result is in conformity with Takele et al. (2021) showed that drought tolerance, disease and pest resistance, higher yield, market demand and others were the preference traits for farmers to choose improved common bean varieties.

Table 6. Farmers preferred traits for common bean variety selection (#14)

Criteria	A	B	C	D	E	F	G	Total score	Rank
High yield (A)		B	A	A	A	F	A	4	3
Disease resistance (B)			B	B	B	F	B	5	2
High market demand (C)				C	C	F	C	3	4
Early maturity (D)					D	F	D	2	5
Less shattering (E)						F	E	1	6
Drought resistance (F)							F	6	1
Seed colour (G)								0	7

The desirable characteristics of improved common bean varieties which are cultivated in farmers field are presented (Figure 5). As the result of the focus group discussion, most of the farmers prefer KAT-B1 among the varieties due to its early maturity behaviour. The same result was also report in the agronomic data where KAT-B1 variety matures within 82.54 days, which is the earliest compared to the other varieties. Most farmers also preferred SER-125 and SER-119 because of their drought tolerance, higher grain yield, resistance to insect pests unshuttering pod. However, DAB-372, KAT-B1 and SAB-632 were the least preferred varieties due to their poor performance in most agronomic traits (susceptible to diseases and insect pests, moderate yield and shattering pod).

Common bean cost of production and feasibility

Common bean production in the study area involves different farming activities. For common bean production, labour cost is the major expenses that farmers incur. Table 7 shows that threshing, land preparation, harvesting, weeding and rouging were the major cost components of common bean production under labour cost items. The total labour cost of producing common bean was 52,304 ETB per hectare. This is relatively lower as compared to the study conducted by Tamirat et al., (2020) common bean labour cost (5444 ETB) in the Central Rift Valley (CRV) of Ethiopia.

Table 7: Common bean cost of production

Labour cost items	Total cost	Share (in %)
Land preparation	11,156.9	21.3
Labour for planting	3,975	7.6

Fertilizer application	1,672.7	3.2
Weed control	7,477.3	14.3
Rouging	7,563.6	14.5
Harvesting	8,102.3	15.5
Threshing, winnow cleaning	11,377.3	21.8
Transportation	9,81.8	1.9
Total labor cost	52,306.9	100

Common bean producing farmers have incurred a highest operational cost of ETB 11,377.3 which accounted for ~~is~~ 21.8% followed by land preparation (21.3%), and harvesting (15.5%) of the total variable cost. The high variability in production costs reflects the differences in the management levels, with the producers who implemented all the recommended practices incurring higher costs. Figure 4 also shows that the cost structure common bean production, in which labour is the most important one followed by land rent expenses, seed cost and fertilizer expenses respectively.

Figure 4: Cost structure of common bean production

The results in table 8 shows that the average yield of common beans using the improved varieties was in the study area as about 2,265.4 kg per hectare which is lower than the varieties potential national average (>2400 kg/ha). Farmers obtained about 41,152.4 ETB per hectare on average from common bean farming. A business is said to be profitable and viable if and only if revenue is greater than the total variable cost, which makes the gross margin positive. The highest gross margin obtained was from SER-119 and SAB-632 varieties. The result of the cost analysis showed mean total revenue of ETB 119,222.2 per hectare and total variable cost of ETB 78,069.8 per hectare.

Table 8: Common bean varieties benefit cost ratio

Benefit-cost analysis	SAB-632	DAB-372	SER-119	SER-125	KAT-B1
Grain yield (kg)	2325.19	2288.33	2338.83	2255.72	2119.15
Grain price (ETB/kg)	50	50	50	50	50
Grain revenue (ETB)	116,259.5	114,416.5	116,941.5	112,786.0	105,957.5
Straw yield (kg)	2500	2350	2300	2400	2350
Straw price (ETB/kg)	2.5	2.5	2.5	2.5	2.5
Straw revenue (ETB)	6250	5875	5750	6000	5875

Total revenue (ETB)	122,509.50	120,291.50	122,691.50	118,786.00	111,832.50
Grain cost production (ETB)	78069.8	78069.8	78069.8	78069.8	78069.8
Gross margin (ETB)	44,439.70	42,221.70	44,621.70	40,716.20	33,762.70
Benefit Cost Ratio (BCR)	1.57	1.54	1.57	1.52	1.43

Source: Demonstration host farmers

Sensitivity analysis

Sensitivity analysis helps for better understand how changes in costs, revenues, or other financial inputs can affect profits, net worth, or other key financial metrics. Table 9 presents sensitivity analysis of common bean due to major inputs output price or production changes. Scenario 1 assumes yield increase by 20% the profit margin of the common bean production enterprise increases to 20%, keeping other factors constant. On the contrary, as production cost increases by 20%, the profitability of common bean production decreases by 43.2% on base case scenario. A 10% decrease in the expected yield and 20% decrease in price may cause a 44.7 % decrease in the profit margin from base case scenario. Pertaining to the changes in yield and market prices of the commodity, with other things being the same, reduction in common bean yield and prices have the high negative effect on the gross margin, gross return, and profit margin. The other scenario of the sensitivity analysis shows that production cost decreases by 20% without output price change may result 77.3% in common bean profit margin. From sensitivity analysis, it can be expected that the most influential factor on a farmer's profit are the yield and market price. Besides, the price and yield change in production cost also has a significant effect on the profit.

Table 9: Sensitivity analysis of common bean production (ETB/ ha)

Scenario	GR	TC	GM	Profit margin (%)
Base case scenario	119222.2	84069.8	41152.4	48.9
Yield increase by 20% & others remain constant	141876.6	84069.8	57806.8	68.8
Production cost increase by 20% & other remains constant	83577.7	78789	4788.7	5.7
Price increase by 30% & others remain constant	153203.9	84069.8	69134.2	82.2
Yield decrease by 10% & price decrease by 20%	87506	84069.8	3436.2	4.2

Production cost decrease by 20% without change in produce price	119222.2	67255.8	51966.4	77.3

Note: GR=Gross revenue; TVC= Total cost; GM= Gross margin

Conclusion and Recommendations

Several production constraints such as drought, moisture stress, low soil fertility, dependence on local cultivars, lack of access to quality improved seeds, lack of awareness on nutritional benefits, as well as poor agronomic practices remains a bottleneck to boost the crop yield and utilization. From the study, considerable variation was observed between improved common bean varieties in yield, adaptation and other agronomic performances. KAT-B1 variety was the earliest to mature and SER-119 was selected for the agronomic superiority by the evaluating farmers. The study further showed that farmers could obtain a higher return by producing improved varieties. However they can harvest a maximum benefit by using SER-119 variety. The sensitivity analysis also showed the most influential factor on a farmer's profit is the yield and market price. The benefit cost ratio also showed the common bean farming is profitable in the study area. Therefore, it is recommended to scale the farmers' preferred and profitable variety (SER-119) in common bean producing areas.

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