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Introduction of improved food-type common bean (*Phaseolus vulgaris* L.) varieties through participatory evaluation and selection for adaptation and important agronomic traits in mid-low altitude districts of Guji Zones, Southern Ethiopia

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ABSTRACT

Aim: The aim of this study was to evaluate and select common bean varieties with high yielding capacity and other superior agronomic traits through farmer's participation in decision making during the selection process.

Materials and Methods: The experiment was arranged in randomized complete block design. In one potential site, three farmers' fields were purposively chosen. The varieties were evaluated for days to flowering and maturity, plant height, number of branches, number of pods, number of seeds, thousand seed weight and grain yield and farmers selection criteria such as plant establishment, lodging, earliness, synchrony to maturity, free of disease and insect pests, drought tolerance, shattering, seed size, seed color, market value and overall field performances.

Results: The result showed highly significant ($P \leq 0.01$) differences among varieties for all studied parameters except number of primary branches per plant. The varieties Nasir, Hawassa-dume and Angar with 3.74 tha^{-1}, 3.13 tha^{-1} and 3.05 tha^{-1} were found to be high in yield, respectively. However, varieties Ibado, Loko and KAT-B9 were the farmers most preferred varieties in terms of their phenotypic traits such as large seed size, uniformity red and red mottled colored seed and early maturity. Participatory Variety Selection (PVS) helped the farmers in selecting the variety that possesses customer preference on market specification.

Conclusion: It was concluded that the area is highly market-oriented, high-yielding varieties were not top ranking in selection list due to their small seed size and low market demand. The promising variety Ibado was selected as the first top ranking followed by Loko and KAT-B9 according to farmers' perception at all three farmer sites.

Keywords: Adaptability; farmers preferences; participatory evaluation; market value

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Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the most important cash crops and source of protein in many lowlands and mid land areas (Amanuel *et al*., 2018). It is well adapted to areas that receive an annual average rainfall ranging from 500–1500 mm with optimum temperature range of 16°C–24 °C, and a frost free period. Usually high temperatures do not affect it if adequate soil water is present, although high night temperature will inhibit pollination (Katungi *et al*., 2009).

Moreover, it performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8 (Kay, 1979).

Consequently, it is known as "the poor man's meat" due to its high protein content, which compensates for the deficiency of meat for the people with low income. The crop is grown by subsistence farmers either as a sole crop or intercropped with cereal and tree crops. The national average yield of common bean is 1.7 tons/ha (CSA, 2018), which is low level caused by different constraints such as drought, lack of high yielding varieties, poor cultural practices, diseases and insect pests.

Its production is concentrated in two regional states: Oromia and the Southern Nation Nationality and Peoples Region (SNNPR), which account about 73% of the total national production (CSA, 2010) produce both white canning and colored food type bean. Farmers in central rift valley prefer white bean while farmers of Southern Ethiopia prefer red bean (Ferris and Kaganzi, 2008). The demand for red bean is high but the production is not satisfied. In Southern Oromia, the local red seeded bean cultivars are popular due to its early maturity, provides an excellent nutritional complement to maize and enset which is the main local dishes and it is a major cash crop of the lowland and mid-altitude districts of Guji zone. Furthermore, the demand for red beans in northern Kenya, associated with drought in these areas, has encouraged production of red beans in this region (Ferris and Kaganzi, 2008). However, improved common bean varieties developed at research centers have not been introduced and evaluated quality traits at farmers field condition in the zone.

Participatory Variety Selection (PVS) by which the field testing of released varieties with the participation of farmers. Therefore, PVS is always an integral part of participatory plant breeding but can also stand alone in an otherwise non-participatory breeding. It also involved in selecting varieties that they judge to be most appropriate for their own uses from a range of fixed (stable) varieties that are tested in the field. Participatory Varietal Selection has shown success in identifying a greater number of preferred varieties by farmers in shorter time than the conventional system, in accelerating their dissemination and increasing cultivar diversity (Weltzien *et al*., 2003). Therefore, adding information on farmers' perspectives of plant and grain trait preferences to these criteria will be helpful to the variety selection process. Research costs can be reduced and adoption rates increased if the farmers are allowed to participate in variety testing and selection (Yadaw *et al*., 2006). Here, farmers and researchers used different parameters and methods to evaluate the tested genotypes. Researchers must contemplate traits chosen by farmers in their varietal development such as seed yield, seed size and overall field performance. The current selection process also confirmed that farmers were capable of selecting important traits for grain yield contributing traits and based on those traits demonstrated to identify superior varieties adapted to local environments. Participatory varietal selections are farmer-centered varietal selections limited to testing of the finished varieties. Farmers evaluate various traits that are vital to them and help to increase on-farm varietal diversity, faster varietal replacement and rapid scaling up. Farmers evaluated and selected the varieties depending on their criteria from the mother's trial. Improved common bean varieties are not yet put under production in the potential areas of Guji zone. Based on the weather condition and soil type, the area was highly suitable for this crop production. So, it is mandatory to introduce this crop to the potential areas of the zone. Therefore, this study was conducted with the objectives to evaluate and select common bean varieties with high yielding capacity and other superior agronomic traits through farmer's participation in decision making during the selection process.

Materials and Methods

The field experiment was carried out in the major common bean producing areas of Guji zone (Adola Rede and Wodera) of Southern Oromia from April to July in 2019 cropping season. One potential site and three farmers fields were selected for the study based on the active involvement of the farmers in the production areas of common bean in the districts.

Experimental Materials and Management

Socio-economic survey was conducted using semi-structured (informal) interview to obtain information on the local needs of the respondents. Based on their preferences, early maturing, red and red mottled common bean varieties were obtained from National and Regional Agricultural Research Centers. Twelve improved common bean varieties were used for the study. The trial was organized in randomized complete block design with three replications on station as mother trial. Other three farmer fields were planted with one replication each considered as baby trials. The plot size was 3m x 2.4m with 6 rows and 10cm spacing between plants, while the net harvested area 6 m^2. To reduce border effect, data was taken from the central four rows. Weeding and other management practices were done as required. The fertilizer rate of 19/38/7 $N/P_2O_5/S$ $kgha^{-1}$ was applied at time of planting.

Data Collection and Analysis

Farmer's preferences were identified using focus group discussions held with 36 households of 20 male and 16 female households through actively encouraging female participation. The households were randomly selected from each kebeles' in the districts. Farmers participated in evaluation and selection of improved common bean varieties at maturity and after harvest from mothers trials through farmer research group. Field days were arranged at different growth stages to collect the data using agreed criteria by research participant. Farmers discussed and agreed on criteria that they thought to be important for selecting a given variety at a particular development stage. They set their selection criteria and ranking of varieties according to their setting criteria.

The participant farmers categorized common bean traits such as plant establishment, lodging, earliness, synchrony to maturity, free of disease and insect pest, drought tolerance, shattering, seed size, seed color, market value (high market demand) and overall performance. The rank sum method of each trait for each variety was used to rank varieties based on farmers' selection criteria. The value of each trait has equal weight. The ranking procedure was explained for participant farmers and each selection criterion was ranked from 1 to 5 (1 = Very poor, 2 = Poor, 3 = Average, 4 = Good and 5 = Very good) for each variety. Simple ranking is a tool often used to identify promising varieties based on farmers' preferences (De Boef and Thijssen, 2007).

Table1. List of common bean varieties tested

No	Variety	Seed size	Seed color	Adaptation area (masl)	Breeder/ Maintainer
1	Angar	Small	Red	1600-2200	BARC
2	Babile	Medium	Red	1600-2200	HU
3	DAB107	Large	Red	1600-2200	MARC
4	Hirna	Large	Red	1600-2200	HU
5	Haramaya	Medium	Cream	1650-2200	HU
6	Ibado	Large	Mottled	1600-2200	BOARC
7	Nasir	Small	Red	1600-2200	MARC
8	Hawassa-dume	Small	Red	1800-2200	HwU
9	KATB9/ Dandesu	Medium	Red	1600-2200	HU
10	Loko	Large	Cream	1300-1900	BARC
11	SER119	Small	Red	1600-2200	MARC
12	Tinike	Large	Red	1600-2200	HU

Key: BARC: Bako Agricultural Research Center, BOARC: Bore Agricultural Research Center, HU: Haramaya University, HwU: Hawassa University; Melkassa Agricultural Research Center

Results and Discussion

Analysis of Variance and Mean Performances

The crop-to-crop differences in all of the parameters investigated were highly significant ($P \leq 0.01$) except number of primary branches per plant (Table 2). Mean squares of various agronomic characters were presented whereas, mean values of different traits were presented (Table 3 and Fig. 1).

Phenological and Agronomic Performance of Common Bean Varieties

KAT-B9 was shorter days to flowering (42 days), and other varieties showed medium days to flowering ranging between (48-51) days. Variety KAT-B9 scored the shortest days to maturity followed by Hawassa-dume and the earliest in maturity when compared to the other varieties. While Tinike, Haramaya and Hirna were late matured varieties. The average days needed for common bean variety to maturity was three months and above. Thus, early maturing varieties have the advantage or adaptable over the late once in environments where rain begins late and ends early.

In terms of plant height, it was ranged from 42.87.0 to 104.47 cm. Haramaya was the tallest variety and had climbing character (104.47 cm) followed by Babile (98.97.3 cm) while the shortest variety was KAT-B9 (42.87 cm).

The higher (5.43) and lower (2.87) primary number of branches were recorded for Ibado and Tinike, respectively. Higher pod number was recorded for Nasir, Angar, Hawassa-dume and SER119 and the lowest was for Haramaya (Table 4). Seeds per pod ranged from 3 to 6 seeds (Table 3). Angar, Hawassa-dume, Nasir and SER119 were recorded maximum number of seeds while Loko, Haramaya and Ibado were minimum in number of seeds per pod (Table 3).

The range of 100-grain weight was 25.63 g to 60.97 g. The maximum 100-seed weight (60.97g) was observed for Loko followed by Hirna (59.83g) and Ibado (58.83g) while minimum 100-seed weight was observed for Angar (25.63g) (Table 4).

Grain yield ranged from 2.03 tha^{-1} to 3.74 tha^{-1} with the grand mean of 2.71 tha^{-1}. Nasir (3.74 tha^{-1}), Hawassa-dume (3.13 tha^{-1}) and Angar (3.05 tha^{-1}) were the top three yielding varieties while Babile (2.03 tha^{-1}) was the lowest yielding variety (Fig. 1).

Varieties Evaluation and Selection Criteria

Farmers' evaluations were conducted in the three baby trials and selection had diversified selection criteria to accept and reject bean variety. The evaluations mean score value for each variety ranged from 8.4 to 13.4 (Table 4). Ibado (13.4) scored the highest value and the lowest was scored by Haramaya (8.4). Loko (11.5), KAT-B9 (11.4) and SER119 (11.1) were ranked second, third and fourth best varieties by farmers, respectively. Both farmers and the researchers used different parameters and methods to evaluate the tested varieties. It is obvious that farmers have demonstrated the ability to select well-adapted and preferred varieties under their circumstances using their own criteria. A range of improved varieties should be available for selection under their participation. Researchers must consider farmers selection traits in their varietal development such as grain yield, seed size, seed color, market value and overall field performance. Generally, the variety should have tolerance to biotic and abiotic stresses and have good marketability and consumer preferences.

Table 2. Analysis of variance for agronomic traits of mother trials

Source of variation	d.f	Mean Squares							
		DF	DM	PH	NPB	PP	SPP	HSW	GY
Replication	2	2.03	23.03	20.32	11.60	14.02	0.20	67.02	0.59
Variety	11	17.97**	34.09**	930.47**	1.79ns	87.08**	2.00**	559.92**	0.63**
Error	22	1.21	2.634	44.94	1.00	16.79	0.10	14.48	0.22
Total	35								

Key: ** = highly significant at the level of 1% probability, ns = non-significant, d.f = degrees of freedom. DF = Days to flowering, DM = Days to maturity, PH = Plant height, NPB = Number of primary branches, PP = Pods per plant, SPP = Seeds per pod, HWS = Hundred seed weight, GY = Grain yield.

Table 3. Mean values of different agronomic traits in the twelve selected common bean

Variety	DF	DM	PH(cm)	NBP	PP	SPP	HSW(g)
Angar	49.33^{ab}	98.33^{b}	91.40^{bc}	4.30	23.87^{ab}	5.50^{a}	25.63^{d}
Babile	50.33^{ab}	97.67^{b}	98.97^{ab}	3.23	13.40^{de}	3.97^{b-d}	49.23^{b}
DAB107	48.67^{b}	99.67^{ab}	78.07^{de}	3.20	14.93^{cd}	4.40^{b}	48.07^{b}
Hirna	51.00^{a}	102.00^{a}	92.83^{bc}	3.27	19.23^{a-d}	3.67^{c-e}	59.83^{a}
Haramaya	50.00^{ab}	101.67^{a}	104.47^{a}	3.27	7.47^{e}	3.40^{e}	35.63^{c}
Ibado	50.67^{a}	97.00^{b}	54.47^{f}	5.43	13.57^{de}	3.43^{de}	58.83^{a}
Nasir	49.67^{ab}	98.33^{b}	82.17^{c-e}	3.30	24.67^{a}	5.13^{a}	26.23^{d}
Hawassa-dume	49.33^{ab}	93.67^{c}	89.03^{b-d}	3.03	21.47^{a-c}	5.27^{a}	27.33^{d}
KAT-B9/Dandesu	42.00^{c}	90.33^{d}	42.87^{g}	4.53	15.87^{cd}	3.70^{c-e}	45.87^{b}
Loko	51.00^{a}	98.00^{b}	79.63^{de}	3.00	17.60^{b-d}	3.30^{e}	60.97^{a}
SER119	49.33^{ab}	97.33^{b}	74.83^{e}	3.40	25.37^{a}	5.20^{a}	27.43^{c}
Tinike	51.00^{a}	101.67^{a}	76.37^{e}	2.87	15.23^{cd}	4.10^{bc}	44.47^{b}
Mean	49.36	97.97	80.40	3.54	17.72	4.27	42.46
LSD(5%)	1.86	2.75	11.35	1.69	6.94	0.55	6.45
CV(%)	2.20	1.70	8.30	28.00	23.10	7.60	9.00

Key: LSD = least significant difference; CV = coefficient of variation

Table 4. Farmer sites of agronomic traits in baby trials and ranking of varieties during 2019.

		Farmer's Traits												
No	Variety	PE	LO	EL	SM	FDP	DT	SH	SS	SC	MV	OFP	Total	Mean	Rank
1	Angar	9	11	11	10	14	13	14	10	13	6	5	116	10.5	5
2	Babile	7	11	10	10	11	9	14	13	12	8	6	111	10.1	7
3	DAB107	8	11	11	10	11	11	12	14	13	10	6	116	10.5	5
4	Hirna	8	10	8	7	10	7	13	15	12	9	6	105	9.5	8
5	Haramaya	7	3	5	7	10	8	15	10	11	10	6	92	8.4	9
6	Ibado	10	15	13	13	13	13	15	15	15	15	10	147	13.4	1
7	Nasir	7	13	13	11	12	13	13	9	10	6	5	114	10.4	6
8	H-dume	7	13	10	11	11	10	14	9	10	6	4	105	9.5	8
9	KAT-B9	6	13	13	13	12	13	11	13	13	12	6	125	11.4	3
10	Loko	7	13	12	13	12	12	14	13	13	10	7	126	11.5	2
11	SER119	9	14	13	11	12	13	13	11	12	8	6	122	11.1	4
12	Tinike	5	13	7	8	12	9	14	13	13	10	7	111	10.1	7

Key: PE = Plant establishment, LO = Lodging, EL = Earliness, SM = Synchrony to maturity, FDP = Free of disease and insect pest, DT = Drought tolerance, SH = Shattering, SS = Seed size, SC = Seed color, MV = Market value and OFP = Overall field performance.

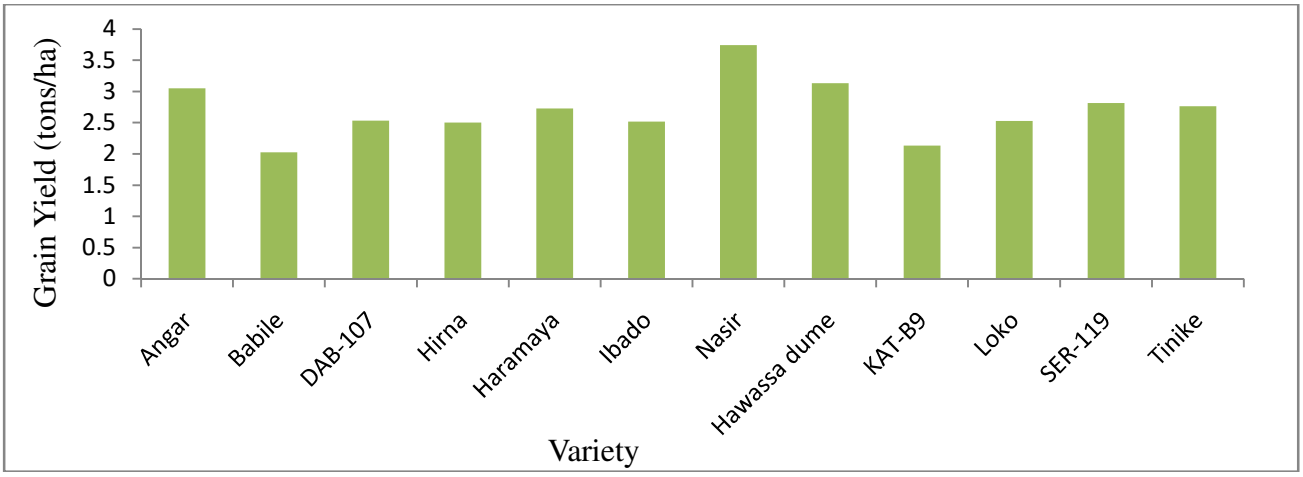

Fig 1. Means for grain yield performance of twelve common bean varieties

This diversity during selection was an indication of the complexity of users' preference. Abraham et al. (2016) reported that when there is more diversity in selection criteria, there is better chance of maintaining on farm diversity since positive traits are seldom found in single variety. However, the result from farmers' evaluation revealed that large seed size and its uniformity red and red mottled colored seed for high market demand (market value) and earliness were the major decisive criteria in retaining and rejecting the variety. Seed color and size are important characters of consumers' preference. Red seed beans are preferred because of the red color imparts to the food after cooking. Similar findings were reported for pure red and red mottled seed color and high yielding variety were the major decisive criteria to accept or reject common bean in Southern Ethiopia (Asrat, 2008 and Abraham *et al*., 2016).

Conclusions

Introducing new common bean varieties through participatory variety selection help the farmers to choose the variety that possesses the character preferred by customer on market and meets their interest. It was observed that as the area is highly market-oriented, high-yielding varieties were not top ranking in selection list due to their small seed size and low market demand. The promising variety Ibado was selected as the first top ranking followed by Loko and KAT-B9 according to farmers' perception at all three farmer sites. Therefore, based on farmers' preference, varieties Ibado, Loko and KAT-B9 are recommended for production for mid-lowland areas of Guji zone and similar agro-ecologies. The identified varieties were scaled up in larger scale to address farmers in the area.

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