On-Farm Performance and Farmer Participatory Evaluation of Newly Released Common Bean Varieties in Oromia Regional State, Ethiopia

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Abstract

Common bean is an increasingly important commodity in the cropping systems of smallholder farmers for food and income generation in drought-prone areas of Ethiopia. Despite its high yield potential on research stations, the actual farmer's yield is low. To minimize the yield gap, a range of high-yielding and disease-resistant common bean varieties were released. On-farm evaluation and demonstrations of newly released Awash-2 and SER-125 varieties with the recommended agronomic practices were conducted to select a best-fit variety for large-scale promotion of the technologies. The study was conducted in East Shewa and West Arsi zones of Oromia Regional state in 2017 and 2018. The field experiments were established on 54 farmers' fields. The new varieties were planted and evaluated alongside the checks (Awash-1 and Nasir). A mean yield of 2448 kg/ha and 2793 kg/ha were recorded from Awash-2 and SER-125 varieties, respectively. Given, similar investments per unit area to produce common beans, the new varieties have higher returns because of their yield advantages. The mean yield of SER-125 is significantly higher than that of the check–Nasir ($t_{(22)}$ =9. 236, p=.000). SER-125 gives a significant yield advantage of 363 kg per hectare. Similarly, Awash-2 gave a significantly higher yield than the standard check–Awash-1 ($t_{(30)}$ =8.049, p=.000) in which the mean yield difference of 464 kg per hectare. Sensitivity analysis shows that the financial profitability of common bean farming is more sensitive to reduction in yield than to increases in price. Farmers' common bean variety selection criteria were yield, drought tolerance, grain color, disease and insect resistance, food taste, and large seed size. Accordingly, Awash-2 and SER-125 were selected as the superior varieties as compared to Awash-1 and Nasir varieties respectively. Generally, common bean producers can earn higher returns if they produce the new varieties with the recommended agronomic practices. Therefore, we advise common bean farmers to pursue large-scale production of Awash-2 and SER-125 in the replacement of the old varieties in the moisture stress area such as West Arsi, East Shewa Zone and similar agro-ecologies.

Keywords: Common bean, Farmer's preference, On-farm performance, Yield gap, Participatory evaluation

Introduction

Common bean, *Phaseolus vulgaris L.*, is widely grown in Ethiopia and it is one of the important commodities in the cropping systems of smallholder farmers for food and income generation (Bedru and Nishikawa, 2012; Mulugeta et al., 2015). The crop is among the suitable grain legume crops for crop rotation and intercropping with maize/sorghum. Under rain-fed growing conditions, common beans can fit into various cropping systems: mono-cropping, sequential/relay-cropping, double-cropping, mixed-cropping, and inter-cropping. It can be grown twice a year in bimodal rainfall patterns. In the first season known as *Belg* (March to mid-May) bean is usually intercropped with maize and sorghum while in the main cropping season, *Meher* (end of June to September), is planted as the sole crop. Farmers prefer the crop because of its fast maturing that enables households to get additional cash income as a result of the possibility for double cropping (Berhanu et al., 2018).

Currently, it is produced by over 3 million smallholder farmers in Ethiopia. In the 2019/20 cropping season, the area planted to common beans was 281,083.49 hectares with 488,583.5 tons production. The major producing areas are concentrated in three regional states (Amhara, South Nations Nationalities and People (SNNP), and Oromia). The three regional states constitute more than 96.7% of the entire common bean area and make 96.8 % of the total common bean production (Figure 1). The produced common beans were utilized majorly for household consumption followed by sale, seed and feed, and in-kind payment for wages (Figure 2).

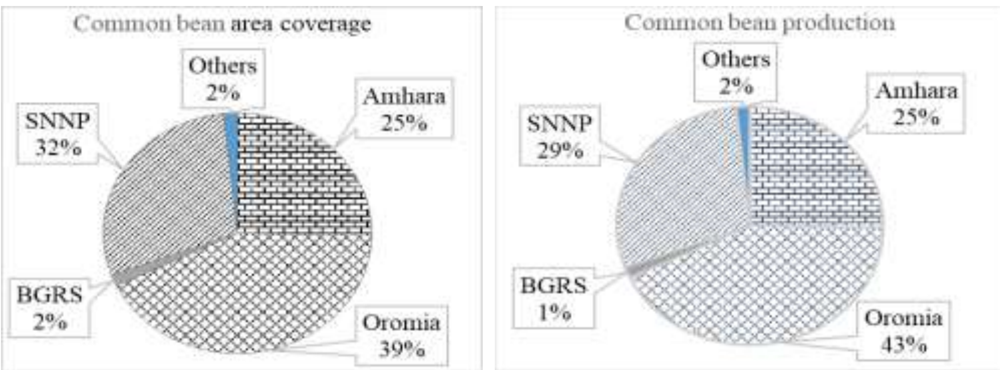

Figure 1. Total area planted and production of common bean across regional states, Ethiopia
Source: CSA, 2020

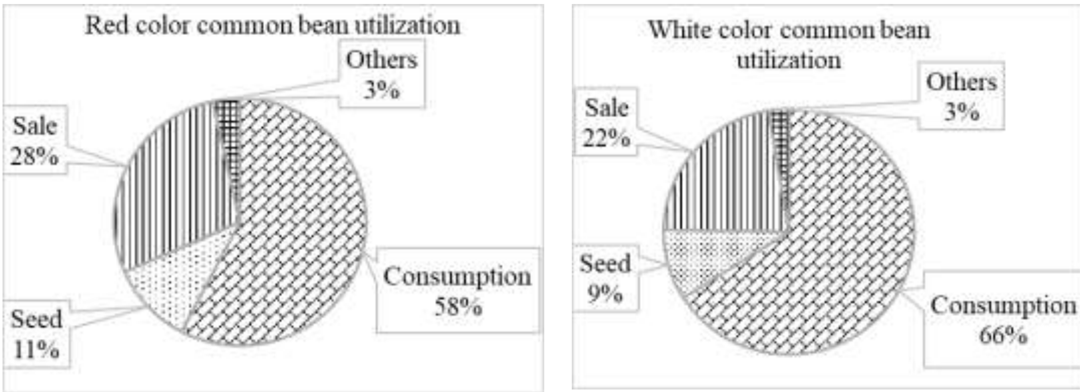

Figure 2. Common bean utilization in Ethiopia
Source: CSA, 2020

Despite the on-research center yield data of 3,500 kg/ha using improved varieties and improved management techniques while the national and East Shewa zone average productivity are 1,738 and 1,841 kg/ha which is significantly below the research result (MoANR, 2016; Berhanu et al., 2018; Endeshaw et al., 2018; CSA, 2020). According to Mulatwa et al. (2017), the low productivity can be attributed to environmental stresses such as drought, insect pests, and diseases. Limited access to the improved common bean seed is also one of the factors constraining productivity (Yitayal and Lema, 2019). The crop productivity can be increased substantially through investment in the dissemination and promotion of improved technologies (Enid et al., 2010). Aiming to enhance the productivity of common beans, the Ethiopian Institute of Agricultural Research (EIAR), has released a range of high-yielding and disease-resistant varieties. Common bean variety release in itself is not an end unless it is utilized as food or sold for cash. In turn, utilization needs the adoption of improved technologies. Hence, on farm improved common bean technology participatory demonstration and evaluation are vital to evaluate the performance of the new varieties to farmers and front-line extension agents to develop their confidence for enhanced adoption and increased yield.

Method and Approach

Description of the study area

The study was conducted in Adama and Adamitulu-Jidokombolcha (AJ) districts in East Shewa and Shalla district in West Arsi zones in Oromia National Regional State. The areas were selected based on their high production potential. The sites were selected in collaboration with the respective district agricultural and natural resource offices. The description of the districts is presented as follows.

Adama district capital, Adama, is located 100 km to the southeast of Addis Ababa. Adama district is located between 08°33'35"– 08° 38'46"N latitude and 39° 10'57"– 39° 30'15"E longitude. The altitude ranges from 1450 to 2300 meters above sea level. The district receives an average annual rainfall of 600–1200 mm with an annual temperature between 15°C and 32°C. Agriculture is the mainstay of economic activities characterized by a mixed-farming of crop and animal production. Among the major crops, tef, maize and common bean are the major crops in area planted. Vegetables and fruits are grown mainly in areas where irrigation facilities are available (Habtamu et al., 2011)

AJ district capital, Batu, is located 168 km, South of Addis Ababa. The district is geographically located between 7° 35”–8° 05” N and 38° 20” –38° 55” E in the northern part of the Rift Valley. The area receives a mean annual rainfall of 690 mm, and it has an altitude between 1500 and 2300 meters above sea level. Its annual temperature varies between 14℃ and 27℃ respectively. The district is characterized by a bimodal pattern of rainfall; with a short rainy season running from February to April and a long rainy season from June to September. However, the pattern of rainfall is usually erratic with fluctuations in the start and end of the season, in addition to the total absence of rainfall at times (Tesfaye, 2008). Shalla district is one of the districts in the West Arsi zone of Oromia National Regional State. Its capital Aje is located 279 km south of Addis Ababa. The area receives annual rainfall ranging from 1000 to 1200 mm, and the main growing season is from June to September. The altitude of the district is between 1000 and 2300 meters above sea level. The mean annual temperature of the district is 22℃ and 25℃. Agriculture is the primary economic activity for 95% of the population. The major crops grown are maize, wheat, common bean, and tef (Mekonnen et al., 2015; Ahmed et al., 2018).

Farmer’s selection and consultation meeting

In consultation with the respective district agricultural experts and development agents, host farmers were selected based on land availability and willingness to host the experiment. Fifty-four farmers were selected (23 for the SER-125 and 31 for the Awash-2) to establish the demonstrations considering each farmer as a replication. In Adama and AJ districts, where farmers mainly cultivating the white-seeded common bean, Awash-2 were planted with the check (Awash-1). Whereas the red-seeded common bean, SER-125, was planted in AJ and Shalla districts with the check (Nasir). To develop an understanding of improved common bean production practices, a consultative meeting was organized for farmers, agricultural development agents, and experts. On the occasion, 54 host farmers, 15 development agents, and 10 mid-level experts were participated.

Field layout and agronomic practices

Awash-2 and SER-125 were planted alongside the checks on 0.25 hectares of land, each 0.125 ha. The planting was done from June 25 to July 5. With a row spacing of 40 cm, 10 cm space between plants, 100 kg/ha of seed, 100 kg DAP/ha was applied during planting. Up to three times hand weeding was done depending on the prevalence of weed infestation. Researchers, extension agents, farmers visited the fields and evaluated during the emergence, flowering, and maturity stages of the crop, and evaluated based on farmers selection criteria. Finally, the yield of Awash-2 and SER-125 were weighed, recorded and compared with that of the checks- Awash-1 and Nasir respectively.

Varietal trait preference and ranking

Focus group discussions were held to identify farmers' common bean selection criteria for the preference of both white and red-seeded common bean types. The list of preference criteria for the common bean was ranked using pair-wise ranking to identify the priority traits of farmers. Based on the criteria set, the focus group discussants ranked the demonstrated varieties in each study area. For the focus group discussion, men and women farmers who have long experience in common bean production were selected in collaboration with respective district agricultural experts.

Method of yield gap analysis

The demonstration trials were conducted for two years at different districts/ locations and a mean yield value for the district yield was calculated. The demonstration data were averaged over the years to calculate the mean yield for the districts. The demonstration yields represented the achievable yields with improved management under farmers' conditions.

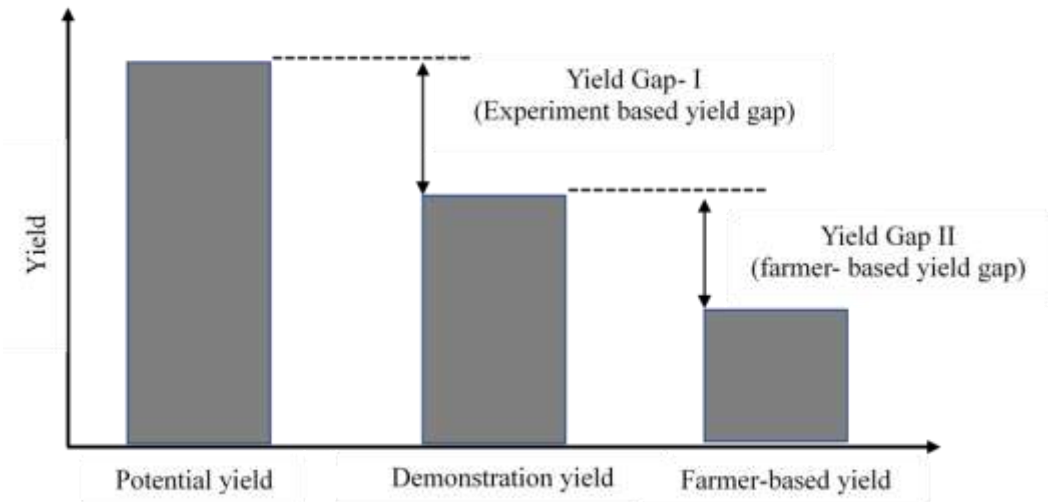

Figure 3. Yield gap as defined by Loblle et al., 2009

The farmer's yield represents yields under farmer management practices. The average production data of the crop in farmers' fields using farmer's practices were obtained directly from the participant farmers. Lobell et al. (2009) divided the yield gap into two types, the gap between research station (potential) and demonstration yield and the gap between demonstration yield and farmers yield (actual). The potential yield is the maximum possible rainfed yield. For the potential yield, the variety Registry Book was consulted for the demonstrated varieties. The crop yield data of the on-farm experiment were used for the demonstration yield.

Data collection and data analysis

Quantitative and qualitative data were collected. The yield was directly measured using a sensitive weight balance. Farmer preference on the variety and important traits were recorded using a data collection sheet. The data were analyzed using descriptive statistics, preference ranking, and yield gap. Finally, the benefit-to-cost ratio was calculated to assess the financial feasibility of improved common bean production.

Results and Discussion

Yield performance

The yield of Awash-2 and SER-125 were compared to the yield performance of their respective checks (Tables 1 and 2). A mean yield of 2,448 kg/ha and 1,984 kg/ha were harvested from Awash-2 and Awash-1 varieties respectively. From the study, we found that SER-125 gave a higher mean yield of 2,793 kg/ha compared with the check mean yield of 2430 kg/ha. This result clearly showed that new varieties have a higher yield. The result conforms with that of MoAL, 2016; Teame et al., 2017; Yitayal and Lema (2019).

Table 1. Summary of demonstration yield result of white-seeded common bean, 2017–2018 (N=31)

District	Variety	Productivity by year (kg/ha)						Combined Mean	SD
		2017 (n=15)			2018 (n=16)				
		Min.	Max.	Mean	Min.	Max	Mean		
Adama	Awash-2	2000	2800	2443	2000	2800	2425	2433	299.2
	Awash-1	1800	2000	1914	1700	2300	1963	1940	168.2
AJ	Awash-2	2100	3100	2513	2413	2900	2412	2463	350.0
	Awash-1	1800	2100	1925	2125	2300	2125	2025	161.2
Total	Awash-2	2000	3100	2480	2000	2900	2419	2448	321.3
	Awash-1	1800	2100	1920	1700	2300	2044	1984	167.5

Source: On-farm demonstration fields; SD=standard deviation

Table 2. Summary of demonstration yield result of red-seeded common bean, 2017–2018 (N=23)

District	Variety	Productivity by year (kg/ha)						Combined Mean	SD
		2017 (n=10)			2018 (n=13)				
		Min.	Max.	Mean	Min.	Max.	Mean		
AJ	SER-125	2600	2800	2748	2600	3333	2939	2852	220.8
	Nasir	2100	2800	2500	2100	2700	2400	2446	216.2
Shalla	SER-125	2560	3000	2816	2600	2833	2683	2739	140.8
	Nasir	2100	2500	2300	2400	2600	2500	2417	158.6
Total	SER-125	2560	3000	2782	2600	3333	2801	2793	188.2
	Nasir	2100	2800	2400	2100	2700	2454	2430	184.5

Source: On-farm demonstration fields; SD= standard deviation

Comparison of yield gaps

The yield gap was analyzed based on the potential yield, demonstration yield, and farmer-based yield. Table 3 presents the difference between the potential, demonstration, and actual farmers' yield. The experiment-based yield gap of red common beans was 707 kg/ha equivalent to a 25% mean yield gap. Under demonstration plots, the yield of common bean with improved variety (SER-125) was 2793 kg/ha, while the mean farmer-based yield of the check was 2430 kg/ha. Thus, the farmer-based yield gap was 363 kg/ha resulting in a 15% of yield advantage. Similarly, the yield gap was calculated for the white-seeded common beans in AJ and Adama districts. The mean value of the experiment-based gap was 652 kg/ha (27 %). The farmer-based mean yield gap was 464 kg/ha (19%) between the demonstration and actual farmers' yields. Due to differences in agronomic practices of smallholder farmers, biotic and abiotic factors, common bean yield differs from 1750 kg/ha, country average yield, (CSA, 2020) to 2793 kg/ha (on-farm demonstration yield). This indicates that there is option and high potential to increase common bean yield by 60% per hectare at the farmers' level by adopting improved varieties, improving the management practices and employing recommended agronomic practices. This is an indication that realized yields at the demonstration sites gave huge potentials for improvement. If this gap is closed, the common bean production will be enhanced.

Table 3. Yield and yield gap of red seeded common beans (kg/ha)

Parameters	Location		Mean	Parameters	Location		Mean
	AJ	Shalla			Adama	AJ	
Potential yield (SER-125)	3500	3500	3500	Potential yield (Awash-2)	3100	3100	3100
Demo. Yield (SER-125)	2852	2739	2793	Demo. Yield (Awash-2)	2433	2463	2448
Nasir (check) yield	2446	2417	2430	Awash-1 (check) yield	1940	2025	1984
Farmer-based gap	406	322	363	Farmer-based gap	493	438	464
Experiment-based gap	648	761	707	Experiment-based gap	667	637	652

Source: On-farm demonstration fields and MoANR, (2016)

There is a significant mean yield difference among the varieties. The mean yield of SER-125 was significantly higher than that of the check–Nasir ($t_{(22)}$=9.236, p=.000). SER-125 gives a significant yield advantage of 363 kg per hectare. Similarly, Awash-2 gave a significantly higher yield than the standard check–Awash-1 ($t_{(30)}$=8.049, p=.000) in which the mean yield difference of 464 kg per hectare. This shows that the recently released improved common bean varieties have a statistically significant yield advantage over the checks.

Benefit-cost ratio (BCR) analysis

The total cost and benefits of common bean production using the new and old varieties are summarized in Table 4. BCR was calculated as the ratio of total revenue (TR) to total variable cost (TVC) which includes costs of inputs: fertilizer, seed, and operation costs like land preparation, planting, weeding, harvesting. The new varieties (SER-125 and Awash-2) have the highest benefit-cost ratio than the check (Nasir and Awash-1). The result showed that even if there is an equal cost of production within the same group of common beans, there is a positive difference in productivity which leads to higher income. For every one birr invested in the production of SER-125 and Awash-2, a farmer gets an additional 1.17 birr and 1.00 birr as a gross return respectively (Table 4). Thus, farmers will be at the high-profit level if they cultivate SER-125 and Awash-2 using associated production practices. In summary, common bean producer farmers can get a high-level benefit if they produce the relatively new common bean varieties in the study area and similar agro-ecologies.

Table 4. Financial returns of improved common bean production

Item	Awash-2	Awash-1	SER-125	Nasir
Overall mean yield in kg/ha	2448	1984	2793	2430
Price (Birr/kg)	16	16	13	13
Total Variable Cost	19,590	19,590	16,730	16,730

Total Return	39,168	31,744	36,309	31,590
Gross Margin	19,578	12,154	19,579	14,860
Benefit Cost Ratio (BCR)	2.00	1.62	2.17	1.89

Source: Demonstration host farmers

Sensitivity analysis

Agricultural is a risky business. Risk analysis consists of determining how sensitive the investment is to different economic assumptions. This is done by holding all other assumptions fixed and then applying the present value to each different economic assumption. It is a technique that highlights the consequences of changes in prices, volumes, rising costs, or additional investments on the value of projects. This helps us to identify which line of decision is most feasible or less risky. It gives the decision-maker more information to use in deciding whether or not to accept the advice of the original NPV analysis (Vernimmen et al., 2014; Lumby and Jones, 2003).

Table 5. Sensitivity analysis of gross margins in white bean for varying output price and yield

Parameters	Base	10% increase in price	10% decrease in price	10% increase in yield	10% decrease in yield
Yield (kg/ha)	2448	2448	2448	2692.8	2204.2
Price (birr/kg)	16	17.6	14.6	16	16
Total return	39168	43084.8	35740.8	43084.8	35267.2
Total variable cost	19590	19590	19590	19590	19590
Gross margin	19578	23495	16151	23495	15677
BCR	2.00	2.20	1.82	2.20	1.80
% change in gross margin		20.01	-17.51	20.01	-19.92

In the common bean cultivation, a 10% increase in price and yield resulted in a 20% and 19% increment in gross margin of the white and red beans respectively. While the decrease in price and yield by 10% resulted in an 18% and 20% decrease respectively in the gross margin of the white beans. Similarly, a 10% decrease in price and yield of red common beans brings a 20% and 39% reduction in the gross margin respectively (Tables 5 and 6). The implication is that common bean profitability is highly sensitive to yield decrease than price.

Table 6. Sensitivity analysis of gross margins in red bean for varying output price and yield

Parameters	Base	10% increase in price	10% decrease in price	10% increase in yield	10% decrease in yield
Yield (kg/ha)	2793	2793	2793	3072.3	2204.2
price (birr/kg)	13	14.3	11.6	13	13
Total return	36309	39939.9	32398.8	39939.9	28654.6
Total variable cost	16730	16730	16730	16730	16730
Gross margin	19579	23210	15669	23210	11925
BCR	2.17	2.39	1.94	2.39	1.71
% change in Gross margin		18.54	-19.97	18.54	-39.09

Trait preference and ranking

Based on the pair-wise ranking, farmers gave high priority for market preference, yield, resistance to disease, and drought tolerance for white-seeded common beans in the Adama district (Table 7). However, in Shalla district farmers gave priority to resistance to disease and insect, yield, and drought tolerance for the red-seeded common bean (Table 8). The result suggests that farmers give weight to qualitative traits on top of considering yield as an important parameter for varietal preference.

Table 7. Farmers' trait preference on the white-seeded common bean varieties in Adama district (n=10)

Selection criteria	A	B	C	D	E	F	G	H	Points	Rank
Resistant to disease (A)		A	C	D	A	F	A	A	4	3rd
Insect resistance (B)			C	D	E	B	B	B	3	4th
Market preference (C)				C	C	C	C	C	7	1st
High yield (D)					D	D	D	D	6	2nd
Drought tolerant (E)						E	E	E	4	3rd
Seed color (white) (F)							F	H	1	6th
Seed size (G)								H	0	7th
Good test (H)									2	5th

Source: Focus group discussion

Table 8. Farmer's trait preference on the red seeded common bean varieties in Shalla district (n=10)

Selection criteria	A	B	C	D	E	F	G	H	Points	Rank
Market preference (A)		B	C	D	E	F	A	A	2	5th
High yield (B)			C	C	B	B	G	B	4	3rd
Resistant to disease (C)				D	C	C	C	C	7	1st
Resistant insect (D)					D	D	D	D	6	2nd
Drought tolerant (E)						E	E	E	4	3rd
Good test (F)							F	F	2	4th
Seed color (red) (G)								G	2	4th
Seed size (H)									0	6th

Source: Focus group discussion

Awash-2 received the higher score weight at all locations (Table 10). The variety had an overall mean weighted evaluation score of 0.85 which is greater than the mean weighted evaluation score of Awash-1. This shows that Awash-2 is the preferred variety over the check. Similarly, the

SER-125 variety preferred more than the check by all traits set by the common bean farmers (Table 9).

Table 9. Preference ranking of the common bean varieties in AJ and Shalla districts (n=14)

Location	Variety	High Yield	Drought tolerant	Market	Grain color	Food tastes	Seed size	Total score	Rank
AJ	SER-125	3	3	2	2	2	2	14	1st
	Nasir	1	2	2	2	2	2	11	2nd
Shalla	SER-125	2	2	2	3	3	2	14	1st
	Nasir	1	2	2	2	3	2	12	2nd

Note: ranking scores out of 3 points with 1= low score, 2= Moderate score, and 3= high score.
Source: Focus group discussion

Table 10. Preference ranking for the varieties using different criteria (n=21)

District	Variety	Yield	Drought tolerant	Disease-insect resistance	Grain color	Food taste	Seed size	Total score	Weight	Rank
ATJK	Awash-1	1	2	2	2	2	3	12	0.67	2
	Awash-2	2	2	3	2	2	3	14	0.78	1
Dugda	Awash-1	1	2	2	1	1	2	9	0.50	2
	Awash-2	2	3	3	3	2	2	15	0.83	1
Adama	Awash-1	2	3	2	3	2	2	14	0.78	2
	Awash-2	3	2	3	3	3	3	17	0.94	1
Weighted mean score (Awash-1)		1.30	2.33	2	2	1.67	2.33	11.63	0.65	2
Weighted mean score (Awash-2)		2.33	2.33	3	2.67	2.33	2.67	15.33	0.85	1

Note: ranking scores out of 3 points with 1= low score; 2= Moderate score; and 3= high score.
Source: Authors' farmer feedback data

Conclusion and Recommendations

The new common bean varieties (Awash-2 and SER-125) found more productive than the older varieties on farmer's fields. Based on farmer on farm evaluation the new varieties SER-125 and Awash-2 were chosen over older ones—Nasir and Awash-1 because of their yield advantages and preferred traits. The traits that were preferred by the common bean farmers are market demand, high yield, resistance to disease and insects, and drought tolerance. Given, similar investments per unit area to produce common beans, the SER-125 and Awash-2 varieties are more profitable because of higher productivity. Hence, promotion and scaling of Awash-2 and SER-125 as the best replacements for Awash-1 and Nasir respectively is recommended in common bean producing areas in the moisture stress area such as West Arsi, East Shewa Zones and similar agro-ecologies.

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