Assessment of on-farm performance of common bean in central rift valley areas of Ethiopia

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Abstract: Common bean (Phaseolus vulgaris L.) is an essential crop in Ethiopia and the Central Rift Valley of Oromia regional state for food and cash. However, the actual grain yield of common bean on smallholder farmers is low (~1.7 t ha⁻¹) compared with the grain yield (~3.0 t ha⁻¹) obtained in the on-station research and relative to a potential grain yield of 3.5 t ha⁻¹. To improve the productivity of the crop, more than 54 high-yielding, multi-disease-resistant common bean varieties were released. This study, therefore, was implemented to assess the performance of the newly released common bean varieties through large-scale demonstrations and create wider demand. This was implemented for two years (2019–2020) on 69 ha by participating 85 farmers. The average grain yield of SER-125, SER-119, and Awash-2 were 2.5 t ha⁻¹, 2.5 t ha⁻¹, and 2.0 t ha⁻¹, respectively. The results of the present study indicated that improved production practices using the recently released varieties resulted in higher grain yield advantages over the farmers’ practices in all districts. The newly introduced varieties were also preferred by farmers because of high-yielding, early maturity, and drought-tolerant traits. There should be an appropriate system that delivers the seed to the common bean producers for the sustainable production of common bean through the deployment of improved common bean technologies. In addition, research institutions should focus on solving insect (Bean stem maggot) and diseases (Rust and Halo blight) to improve the production of common bean in the study area and areas with similar agro-ecology.

Keywords: Challenges; Farmers’ preference; Improved production practices; large-scale; Grain yield gap

1. Introduction

Common bean (Phaseolus vulgaris L.) is one of the most important pulse crops grown in Ethiopia, both in area coverage and quantity produced (CSA (Central Statistical Agency), 2021). Common bean is grown twice a year (Belg and Meher season) in some areas with bimodal rainfall patterns. In the first season known as Belg (March to mid-May), common bean is usually inter-cropped with maize (Zea mays L.) and sorghum (Sorghum bicolor L.) while in the main cropping season, the Meher (end of June to September) it is planted as the sole crop. The crop is cultivated mostly in the Oromia (43%), Amhara (25%), and Southern Nations Nationalities and Peoples regions (29%). Farmers prefer the crop because of its fast maturing that enables households to get additional benefits of income through selling of surplus resulting from double cropping in a year (Berhanuet al., 2018).
The land area for common beans production in Ethiopia by 2014 was 323,318 ha, and it was reduced to 311,583 ha by 2020. Even though the area coverage is reduced by 4%, the total crop production increased from 51,373 ton to 55,256 ton (CSA [Central Statistical Agency], 2021). This increase was attributed to the productivity level of common bean grain yield, which was improved relative to the actual land area harvested to 1.8 t ha⁻¹ (CSA [Central Statistical Agency], 2021). However, the grain yield obtained under farmers field is far below the corresponding grain yield (~ 3.0 t ha⁻¹) recorded at the research stations (MoAaNR [Ministry of Agriculture and Natural Resource], 2016). This shows that the grain yield gap between the farmers’ and the research-based practices is about 1.2 t ha⁻¹ against the potential grain yield of 3.5 t ha⁻¹ reported in Ethiopia (Amare & Kassaahun, 2021; Berhanu et al., 2018; Mohammed & Feleke, 2022). Therefore, there is a large grain of 34% to be bridged between farmers and the potential yield in the production, of common bean that has been filled through further research using advanced technologies coupled with innovations in crop production chain.

The newly released varieties were popularized through pre-extension demonstrations in the study areas. As a result, common bean farmers showed their interest in cultivating SER-125, SER-119, and Awash-2 varieties for their high-yielding, early maturity, and drought-tolerant traits (Fistum et al., 2021). The large-scale demonstration was conducted to assess and explore the farmers’ feedback subsequent to the pre-extension demonstration.

2. Materials and methods

2.1. Description of the study area

The study was conducted in three districts, namely, Shalla, Shashemene, and Adama. The study areas were selected based on the potential and area coverage of the crop. The selection was done in collaboration with district experts of the respective agricultural and natural resource offices.

Adama district is located between 8°33’35” N to 8°38’46”N and 39°10’57” E to 39°30’15”E. Its annual temperature and rainfall vary between 15°C and 20°C and 700 mm-800 mm, respectively (Hurgesa et al., 2019). Shalla district is one of the districts in West Arsi Zone of Oromia National Regional State. 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 m above sea level. The mean annual temperature of the district is 22°C and 25°C. Agriculture is the primary economic activity for 95% of the population where maize, wheat, common bean, and tef are the major crops cultivated by the farmers (Ahmed et al., 2018). Shashamane district is found around 253 km far from Addis Ababa to the South. The geographical extent of Shashamane district ranges from 7° 04’50” to 7° 22’45” N and 38° 23’00” to 38° 48’00” E. Its total area coverage is 76,787.86 hectares. The elevation of the district varies between 1683 m to 2742 m above mean sea level. Annual total rainfall distributions range from 862 to 1111 mm. Bimodal rainfall is common and the peak rainy season is in May followed by the second peak in August. The major crops produced in the district include maize, wheat, barley, tef, common bean, and potato (Tadesse et al., 2016).

2.2. Description of common bean varieties cultivated

In the study areas, improved varieties of common beans with recommended practices were introduced by the Melkasa research center of the Ethiopian Institute of agricultural research. In the study area six local cultivars: Bora, Waka, Dima, Balonde, Fosolia, and Gale-Abesha; and three improved varieties: Awash 1, Mexican 142, and Roba 1 are cultivated by the farmers. To grow these varieties, farmers mostly use informal local seed sources. This constitutes farmer-to-farmer exchanges, using their seed stocks, and using undeveloped seed markets (Tebeka et al., 2017). As a result of this, the productivity of the crop was low compared with the newly released varieties’ potential (Fistum et al., 2021).
2.3. Site and farmers selection
For the study, representative kebeles from each district were purposively selected based on their accessibility for field monitoring and follow-ups and potential for common bean production. Awara Gama and Bekele Deya kebeles from the Shalla district, Mermers and Guraja Furda kebeles from Adama districts and Oine Chafo from Shashemene district were selected in collaboration with district agriculture and Natural resource offices. Based on farmers’ interest and experience level in the common bean production, willingness to manage and allocate land for the activity, and willingness to collaborate with extension agents and researchers, host farmers were selected. Finally, from the five kebeles, 85 common bean producer farmers (49 from Adama, 27 from Shalla and 9 from Shashemene districts) hosted the demonstration in 69 hectares of land (Table 1).

2.4. Approaches followed
The large-scale demonstrations are implemented on a relatively medium-scale after technologies prove their performance under pre-extension demonstration (Derese, 2020). In the past three years, demonstration and evaluation of newly released varieties of common bean were undertaken and three varieties (SER-119, SER-125, and Awash-2) were recommended for large-scale promotion. The large-scale demonstration of common bean was conducted for two consecutive years (2019–2020) in a clustered sizeable area. Several farmers were participated to create wider demand, enhance the adoption of improved production practices of common beans, and create and strengthen linkages among actors as shown in Figure 1.

The selected farmers and development agents took part in a brief orientation on the large-scale demonstration plan before the implementation. Based on the orientation, roles were defined. The districts assigned to play the role of selecting farmers provide technical information and inputs required to participant farmers, regularly follow-up and keep records, facilitate information exchange between farmers and stakeholders, while the Melkassa research center provides improved seed, provide technical backstopping and training, organize field days jointly with the districts, develop extension materials, and organize consultative workshops. In line with orientation, training (practical and theoretical) was provided on the different components of the improved production practices for the farmers, extension experts on the second week of July 2019 and 2020. A seed rate of 0.1 t ha$^{-1}$ per hectare was used. Chemical fertilizer (0.11 t ha$^{-1}$ NPS fertilizer per hectare rate) was applied. The 6.9 ton of seeds of the three varieties to 85 hosting farmers. The cost of fertilizer including field management was covered by the farmers.
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Researchers and agricultural experts executed periodic evaluations and inspections of farmers’ fields. To popularize the improved production technology (Table 2), field days were arranged in all study locations in both years. The total number of farmers who took part in the field day was 355 farmers (284 males and 71 women); 68 district experts and development agents (55 males and 13 women) and 24 researchers attended the field days organized. Besides, on the field day, to disseminate the performance of improved common bean production practices for the wider community, the Oromia Media Network recorded and aired a video. In addition, 500 leaflets were prepared on improved common bean production practices and distributed to stakeholders. At the end of the visit, group discussion to grasp farmers’ feedback and reach a common consensus with partners for future scale-up. According to farmers’ observation, the new varieties captured their interest mainly because of their yield advantage, and their early maturity characteristics. Finally, the yield performance of the improved common bean production practices was compared to the farmer’s cultural common bean production practices.

2.5. Data collection and analysis
For the study, quantitative and qualitative data were collected. The grain yield data was collected by harvesting plants in the whole plot. Individual plant harvests in each plot were weighed and summed to obtain total production and grain weight was determined after threshing and converted into grain yield on hectare basis. The number of participants involved in the training and field days disaggregated by sex was also recorded. On the other hand, qualitative data were collected on farmers’ feedback on the technology demonstrated. The challenges faced by farmers in common bean production were recorded. The collected data were analyzed using descriptive statistics and gap analysis.

3. Results and discussions

3.1. Demography of the farm households
In the large-scale demonstration, a large number of male (86%) participated in the farming activities compared with female (14%). From this, it can be understood that the probability of participating female farmers in hosting a demonstration is low in the large-scale demonstration approach. This may be due to large-scale demonstration gives priority to clustering land than farmers. The mean age of the target households was about 40 years with the youngest being 18 and the oldest 70 years. The average family size for the demonstration host farmers was 6. The mean landholding was about 1.7 ha. The target farmers have 3 years of education on average. The average farmer’s experience in common bean farming was 21 years (Table 3).

3.2. Yield performance
The mean grain yield performance of common bean varieties was compared (Table 4 and Table 5). Common bean variety SER-119 produced the highest maximum grain yield (3.07 t ha⁻¹). The mean grain yields of 2.02 t ha⁻¹ and 2.53 t ha⁻¹ were obtained in Awash-2 and SER-125 common bean varieties, respectively. The grain yield obtained in the new varieties, including the deployment of improved production practices, was higher than those obtained with the farmers’ practice. This verifies the importance of adopting improved practices for common bean production corroborates that of Yitayal and Lema (2019).
| District | kebele  | Location | Total area covered | Mean area covered | Participant farmers |
|----------|---------|----------|--------------------|-------------------|---------------------|
|          |         |          | Latitude | Longitude | Altitude | M       | F       |
| Shalla   | Awar Ama| 038° 26.83’ | 07° 16.87’ | 1682     | 20 (29%) | 1       | 17      | 3       |
|          | Bekele Deya | 038° 24.52’ | 07° 17.29’ | 1673     | 10 (14%) | 1.4     | 7       | 0       |
| Adama    | Mermersa | 039° 24.32’ | 08° 24.6’   | 1655     | 7 (10%)  | 1.8     | 4       | 0       |
|          | Guraja   | 039° 22.3’  | 08° 36.67’  | 1654     | 22 (32%) | 0.5     | 36      | 9       |
| Shashemene | OineChafo | 038° 32.76’ | 07° 13.88’  | 1799     | 10 (10%) | 1.11    | 8       | 1       |
| Total    |         |          |          |          |          | 69      | 0.81    | 72      | 13      |
The result of the study indicated the improved production practice using the recently released varieties of common bean has a higher yield increment over the yield of common bean using farmers’ practice in all districts. The larger yield increment was reported from Shalla district, with a 46% increment with SER-119 variety. The minimum (12%) yield increment was obtained in the Adama district with Awash-2 variety (Table 6). This shows there is a yield advantage in adopting the improved production practices of common bean. The result suggests the positive effects of improved technologies over the existing farmers’ practice towards enhancing the yield of common beans with its positive effect on yield.

### Table 2. Comparison of Improved Common Bean Production Practices and Farmers’ Practice

| Specifics                  | Improved practices | Farmers practice |
|----------------------------|-------------------|------------------|
| Seed rate (t ha⁻¹)         | 0.1               | 0.1–1.2          |
| Seed source                | formal            | informal/savings |
| Planting time              | second week of July| first week of July|
| Use of an improved variety | SER-125, SER-119, and Awash-2 | local cultivar (unidentified) |
| Method of sowing           | row planting      | row planting     |
| Seed quality standards     | 90% germination and 100% purity | unknown |
| Spacing(cm)                | 40x10 cm          | not uniform      |
| Nutrient management        | 0.1 t ha⁻¹ of NPS | < 0.1 t ha⁻¹     |
| Weeding                    | two-three times   | one time         |
| Farming situation          | rain fed          | rain fed         |

### Table 3. Demographic characteristics of target farmers (N = 85)

| Location     | Land holding | Age | Family size | Farm exp. | Edu. level |
|--------------|--------------|-----|-------------|-----------|------------|
| Adama        | 1.4          | 39  | 5           | 19        | 3          |
| Shalla       | 2.0          | 41  | 7           | 22        | 4          |
| Shashemene   | 2.1          | 43  | 9           | 26        | 2          |
| Total mean   | 1.7          | 40  | 6           | 21        | 3          |
| SD           | 1.53         | 11.74| 2.92        | 11.39     | 3.59       |

### Table 4. Yield performance

| Yield         | N  | Min. | Max. | Mean | S. D |
|---------------|----|------|------|------|------|
| SER-119       | 21 | 1.80 | 3.07 | 2.49 | 0.39 |
| SER-125       | 15 | 1.80 | 2.90 | 2.53 | 0.27 |
| Awash-2       | 49 | 1.40 | 2.95 | 2.02 | 0.38 |

### Table 5. Mean yield performance across locations (ton/ha), (N = 85)

| District      | Varieties | Mean productivity over year | Mean yield | S.D |
|---------------|-----------|-----------------------------|------------|-----|
|               |           | 2019 (n = 29) | 2020 (n = 56) |     |
| Adama         | Awash-2   | 1.91            | 2.08        | 2.02 | 0.38 |
| Shalla        | SER-119   | 2.17            | 2.85        | 2.57 | 0.42 |
|               | SER-125   | 2.44            | 2.57        | 2.53 | 0.27 |
| Shashemene    | SER-119   | -               | 2.39        | 2.39 | 0.36 |

The result of the study indicated the improved production practice using the recently released varieties of common bean has a higher yield increment over the yield of common bean using farmers’ practice in all districts. The larger yield increment was reported from Shalla district, with a 46% increment with SER-119 variety. The minimum (12%) yield increment was obtained in the Adama district with Awash-2 variety (Table 6). This shows there is a yield advantage in adopting the improved production practices of common bean. The result suggests the positive effects of improved technologies over the existing farmers’ practice towards enhancing the yield of common beans with its positive effect on yield.
There is a significant mean yield difference among the varieties (Table 7). The mean yield of SER-125 was significantly higher than that of the farmers’ practice. SER-125 gave a significant yield advantage per hectare. Similarly, SER-119 and Awash-2 gave a significantly higher yield than the farmers’ practice. This shows that the improved production practice of common bean has a statistically significant yield advantage over the farmers’ practice in the study areas. This shows that there is an option to increase the yield up to 1 t ha\(^{-1}\) by adopting improved varieties and improving the management practices. This is a sign that realized yields at farmers’ farms still have huge potential for improvement. If this gap is closed, it will enhance the common bean production in the study area and similar agro ecologies.

### 3.3. Farmers’ feedback
Information about the farmers’ preferences was collected besides the grain yield performance. Guideline questionnaire were prepared to catch the feedback from all farmers who took part in the demonstration. Twenty-four farmers were selected among the common bean producers and major challenges and preferences were identified. Farmers who participated in the Shalla district preferred the newly introduced varieties (SER-119 and SER-125) over the local because of tolerance to disease, drought tolerant/ early maturity, good test, red seed color, and market preference. In contrast, the local variety of common bean produced less grain yield, and it was susceptible to disease, and it took long period to reach maturity (late by two weeks). Similarly, in Adama district, the participant farmers also showed their interest in cultivating in larger areas for the coming cropping calendar. The participant farmers in the field visit requested the seed multipliers and district agricultural office for the delivery of the newly introduced varieties in the coming cropping calendar so that they can cultivate and earn good production and income.

Farmers also explained the key challenges in producing common beans. In Adama district, shortage of rainfall, the prevalence of insect (bean stem maggot) improved seed shortage and prevalence of disease (rust and halo blight) are considered the major challenges of common bean producers. In Shalla district, insects (bean stem maggot) were the first key challenges followed by disease (rust) and shortage of rain in terms of intensity and poor distribution. Similarly, farmers identified that limitation of improved seed was a major challenge to common bean production in the Shashemene district. As it was for Adama and Shalla districts, farmers in Shashemene district also identified insect and disease as the challenge for common bean production.
4. Conclusions and recommendations

The finding of the present study showed that the improved practices of common bean production resulted into better grain yield performance than the adopted farmers’ practices. Therefore, farmers can increase grain yield to 47% and income by replacing farmers’ practice with improved practices. A large-scale demonstration is a successful approach in showing the potential of the technology and enhancing the production and productivity of common bean through addition of knowledge, enhancement of attitude, and improvement of skills to farmers. Therefore, it is important that the offices of agriculture and natural resource scale-up the improved production technology of common bean to a large number of farmers in similar agro-ecologies. Furthermore, seed producing/multiplying enterprises, unions, or organized seed producer farmers should continuously and consistently multiply and supply the seeds of SER-125, SER-119 and Awash-2 common bean varieties to ensure sustainable seed supply in the study area. Research institutions should also give attention in solving problems of disease and insect in the fields under common bean production by farmers.

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