Participatory variety selection for released white common bean varieties in South Gondar Zone, Ethiopia

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ABSTRACT

Participatory variety selection plays a vital role in adopting improved crop varieties into a new growing area. Farmers' preferences across locations and growing seasons must be taken into account to introduce improved varieties that farmers will accept. Evaluating improved common bean varieties in specific agro-ecologies is a key activity to enhance the productivity of the crop. The purpose of this study was to identify adapted, high-yielding, disease-resistant, and farmers' preferred white common bean varieties in the south Gondar zone, Ethiopia. Seven released white common bean varieties were evaluated in the mother and baby trial system using Randomized Complete Block Design replicated three times during the 2019 cropping season at the farmers' field of Libokemkem and Simada districts. Seed shape, maturity days, disease reactivity, pod number/plant, and seed number/pod were utilized as variety selection criteria during field observation to determine varieties preferred by farmers.

The results revealed that among the evaluated varieties, Awash-2 (1722.7 kg ha⁻¹) and Awash-1 (1509.8 kg ha⁻¹) produced considerably higher yield at Libokemkem whereas Awash-Melka (3888.1 kg ha⁻¹), Batu (3697.6 kg ha⁻¹), Awash-2 (3463.9 kg ha⁻¹), Mexican-142 (3455.6 kg ha⁻¹) and Awash-1 (3235.3 kg ha⁻¹) were found as high-yielding varieties at Simada. When comparing grain yields at both locations, Awash-2 and Awash-1 are consistently good yielder varieties, which is one of the most important features for the farmers. Based on the farmers' preference, Awash-2 was consistently preferred and selected by the farmers across the two locations. Awash-2 is consistent both in the amount of grain yield and its acceptance by the farmers across the two locations and is suggested as a promising variety that needs to be promoted, multiplied, and disseminated to the farmers of the study areas for cultivation. Assessment of the varieties for Anthracnose and web blight diseases showed no or little and insufficient economic injury and the varieties were generally categorized as less susceptible and intermediate in their response to the diseases.

1. Introduction

In Ethiopia, the common bean (*Phaseolus vulgaris* L) is an important pulse crop for food security and as a commercial product. It grows throughout Ethiopia and is becoming a more important product in smallholder farmers' cropping systems for food security and income. The Rift Valley is where the majority of production takes place. Depending on the type, it may adapt to a wide range of climatic conditions, from sea level to over 3000 m above sea level (Gebre- Egziabher et al., 2014). However, due to poor pod sets caused by high temperatures, it does not grow well below 600 m (Dev and Gupto, 1997). The crop is adapted to low and medium altitudes ranging from 900 to 2100 m above sea level (EEPA, 2004). But, it grows well between 1400 and 2000 m above sea level (Fikru, 2007). The crop thrives at a temperature of 24 °C and receives an average of 200–600 mm of rainfall per year (EEPA, 2004).

Common bean accounted for 19.15 percent (about 306186.60 ha) of the area under pulses and 17.49 percent (about 5209793.27 quintals) of pulse production in Ethiopia in 2017/18 (CSA, 2018). White and red bean varieties are most commonly grown in Ethiopia. White beans are the canning types grown mainly for the export market.

Rashid et al. (2010) observed that demand for Ethiopian beans increased gradually in Yemen, India, Italy, the Netherlands, Belgium, and Romania, but was erratic in Sudan, the United Arab Emirates, Pakistan, Morocco, and Saudi Arabia. Ethiopian bean production increased more than doubled from 138 to 463 thousand tons between 2005 and 2012 (FAO, 2015); and reached more than 520 thousand tons in 2017 (CSA, 2018) due to increasing demand in local and international markets.

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According to FAO (2015), export sales of the crop have more than tripled from time to time and since 2010, the white bean has been fully subjected to export, with legislation requiring that it be sold through the Ethiopian Commodity Exchange (ECX). In addition, to meet the demand in the domestic and international markets, the country’s research centers have developed improved varieties focusing on pure red and pure white beans. All factors of production being constant, the explanation for the difference in yields is that most farmers in developing countries grew old varieties and, few better varieties were developed because they did not have sufficient exposure to new varieties (Schwartz and Corrales, 1989; Witcombe et al., 1996).

Improved varieties should be tested for their adaptation to specific agro-ecologies and made available to farmers as soon as possible to reduce the yield gap caused by lack of access to improved varieties and to increase the country’s production and export earnings from these white bean varieties. The selection of improved varieties through direct farmer participation is one method of introducing improved varieties mainly to farmers. Generally, there have not been evaluations and selection of such released white bean varieties in and around the research sites, especially with the direct participation of farmers. Therefore, the study was conducted to find adapted and high-yielding varieties desired by farmers in the study area.

2. Materials and methods

2.1. Study area description

The trial was conducted in Libokemkem and Simada districts in the South Gonder Zone of Amhara Region of Ethiopia during the 2019 main cropping season. The two locations are 167 km apart and are among the promising bean-growing areas in the zone. The study sites were chosen based on their respective potential for bean production and the crop’s market demand in the study areas. Simada is located at 11°29’ 59.99” N latitude and 38°14’ 60.00” E longitude (https://latitude.to/article-s-by-country-et/ethiopia/229186/simada) with elevations ranging from 1196 to 3525 m above sea level and divided into three climatic zones: middle altitude (40 %), highland (10 %), and lowland (50 %) (Meseret, 2011). Annual rainfall for Simada ranges from 1000 to 1500 mm and seasonal climatic detail of the site in the year of the experiment is presented in Figure 1. The main soil types in Simada are red, brown, black, and gray, which account for about 30%, 30%, 25%, and 15% of the total area, respectively, with red and brown soils being the most common (Marye, 2011). According to the World Reference Base for Soil Resources, 2014 (update 2015), the soil type of Simada is classified into Lithic Leptosol (50%), Eutric Leptosol (30 %), and Eutric Cambisol (20 %) which is mapped by FAO (1990) and generated from ILRI, CIAT, CCAFS (2014) using the location’s latitudinal and longitudinal coordinate values. The major crops grown in Simada include cereals and pulses, such as beans. Libokemkem is found between 12°19’ 60.00” N latitude and 37°39’ 59.99” E longitude (https://latitude.to/articles-by-county-et/ethiopia/305357/kemekem) with an altitude ranging from 1800 to 2850 m above sea level (Berhanu, 2009). The rainfall ranged from 73-372 mm from May to October of the growing season and annual rainfall and temperature distribution for the growing season is presented in Figure 2. The soil type of Libokemkem is 60 % clay loam, 14 % silt loam, and 26 % clay soil Jenber et al. (2020). Farmers in the district grow local bean varieties for double cropping, where chickpea is planted after beans are harvested to take advantage of the soil moisture reservoir. Three consecutive years’ monthly average rainfall distribution of the study sites is depicted in Table 1.

2.2. Experimental design and fieldwork

The study was laid out in a randomized complete block design (RCBD) with three replicates. The experimental unit was 2.4 m x 4 m (9.6 m²), with plants 0.1 m apart and rows 0.4 m apart. Each plot contained six rows of plants, four of which were used in the middle for data collection and the outer ones as border plants. The plots were 0.5 m apart while the blocks were 1.5 m apart. The experiment was conducted as a mother and baby experiment in the farmers’ field. According to Amhara Regional Agricultural Research Institute (ARARI) protocol on participatory variety selection (PVS) (ARARI, 2018, unpublished guide), mother trial is defined as the trial that is managed by a researcher and can be conducted at a research site, farmer training center or farmers’ field with a well designed and replicated trial. Baby trial refers to the trial conducted jointly by farmers, extension workers, and researchers and conducted only in farmers’ fields, involving farmers in the process of variety selection. Field observation and farmer preference data are collected in this baby trial, which is a single replicate of the mother trial. Three baby trials were set up at both trial sites at specific distances from the respective mother trials, with the spacing between plants and row the same as in the mother trial. All agronomic practices were fully implemented for the mother and baby trials of both locations. The study sites were plowed three times by using oxen. After the soil is prepared for sowing, two seeds per hill were planted with the recommended spacing, and thinning was done 15 days after emergence. Seeds were planted on 25, Jun 2019 at Libokemkem and 11, Jul 2019 at Simada at the time when the particular experimental sites received the optimum amount of moisture for germination. Two rounds of hand weeding were undertaken during the growing period of the experiment and 100 kg ha⁻¹ of NPS fertilizer was applied at planting time. Farmers conducted variety evaluation and selection in the baby trials at each location during the crop maturity period. Depending on the maturity of the varieties, harvesting was done from the end of September and of October 2019 at Libokemkem and Simada, respectively. Border rows were harvested as a grain and the central rows for the measurement of the data. Finally, the harvested product from the central rows was sun-dried, threshed and measurements were made for grain yield and one hundred seed weight.
The maturity stage of the crop. Of farmers leaving the two outermost rows as border plants. Harvesting and threshing all plants from the four central rows of each plot. Agricultural experts from districts, development agents, and selected representatives from the Department of Agriculture, south Gondar zone, Simada in 2019 cropping season.

**Table 1. Monthly average rainfall distribution of Simada and Libokemkem in 2018, 2019, and 2020 cropping seasons.**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual rainfall | Mean annual rainfall | Standard deviation |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----------------|----------------------|--------------------|
| Simada | 2018 | 11.2 | 16.5 | 43.2 | 42.9 | 76.9 | 124.7 | 384.5 | 404.8 | 166.7 | 84.5 | 26.1 | 15 | 1397 | 116.41 | 138.33 |
| | 2019 | 11.2 | 16.9 | 43.5 | 42.7 | 77.5 | 124.8 | 384.8 | 405.1 | 166.4 | 84.2 | 27.0 | 15.2 | 1399.3 | 116.61 | 138.32 |
| | 2020 | 11.3 | 17.3 | 43.8 | 42.5 | 78 | 125 | 385.2 | 405.3 | 166 | 83.9 | 27.9 | 15.4 | 1401.6 | 116.80 | 138.31 |
| Libokemkem | 2018 | 7 | 7.7 | 22.7 | 28.1 | 83.8 | 149.5 | 371.8 | 357.6 | 140.6 | 73.8 | 27.7 | 13.9 | 1284.2 | 107.02 | 129.91 |
| | 2019 | 6.9 | 8.2 | 22.9 | 28.1 | 84.5 | 149.5 | 372.2 | 357.9 | 140.6 | 73.6 | 28.3 | 13.0 | 1285.7 | 107.14 | 130.01 |
| | 2020 | 6.9 | 8.6 | 23.1 | 28.1 | 85.3 | 149.5 | 372.5 | 358.2 | 140.6 | 73.5 | 29.0 | 13.2 | 1288.5 | 107.38 | 130.02 |

**2.3. Experimental materials**

Seven improved white common bean varieties (Table 2) were collected from Melkassa Agricultural Research Center and evaluated for their performance and farmers' preferences in the study areas.

**Table 2. List of improved common bean varieties used at Libokemkem and Simada in 2019 cropping season.**

| Variety         | Year of Release | Seed color | Seed size |
|-----------------|-----------------|------------|-----------|
| Awash 1         | 1990            | White      | small     |
| Awash-Melka     | 1999            | White      | small     |
| Mexican-142     | 1973            | White      | small     |
| Awash-2         | 2013            | White      | small     |
| Batu NA         | 2015            | White      | medium    |
| SAB-736         | 2005            | White      | medium    |

**2.4. Data collection**

Data were collected for flowering days: maturity days, plant height, number of branches per plant, pod number per plant, number of seeds per pod, the weight of one hundred seeds, and grain yield. Data for days to flowering, maturity days, one hundred seeds weight, and grain yield were taken on a plot basis and the rest of the data were recorded on a plant basis by taking ten randomly taken plants of each plot. Flowering days were taken as the number of days from the date of planting to the time when 75% of the plot population produces their first flower. The number of days from the date of planting to the time when 75% of the plants in a plot reached physiological maturity, which is recognized by the leaves and pods becoming yellow, was recorded as days to maturity. Plant height (cm) was measured from the base of the plant (soil surface) to the tip of the plant in 10 (ten) randomly selected plants from the middle rows. The average number of branches of 10 (ten) randomly taken plants from the middle four rows of each plot at maturity time was used to calculate the number of branches per plant. The number of pods per plant was taken as the average number of pods obtained from 10 (ten) randomly taken plants from the four central rows at the maturity period. The number of seeds per pod was also obtained as the average number of seeds from all the pods of 10 (ten) randomly taken plants that were used for the determination of the number of pods per plant. One hundred seeds weight (gm) was measured by counting manually 100 seeds from a bulk of threshed seeds of each plot. Grain yield (kg ha$^{-1}$) was determined by harvesting and threshing all plants from the four central rows of each plot leaving the two outermost rows as border plants.

**2.5. Farmers' participatory varietal selection (preference data collection)**

Field visits to the baby trial plots were organized at both sites during the maturity stage of the crop. Officials from Debre Tabor University, representatives from the Department of Agriculture, south Gondar zone, Agricultural experts from districts, development agents, and selected model farmers from each site participated in the evaluation and selection program. Twenty model farmers, from both research sites, were recruited by their kebele development agents for field evaluation and variety selection. Field visits were conducted independently at each site.

Groups of farmers were formed and they listed the evaluation criteria for the varieties based on their interest. Discussions in each group were made and the farmers in each group prioritized and jointly agreed on five characters namely: seed shape, maturity days, disease reaction, pod number/plant, and seed number/pod. The farmers used a pair-wise ranking approach to rank each evaluation criteria, and the ranks were used to determine the weight of the criteria. Following the identification of their selection criteria, the farmers were given instructions on how to evaluate the varieties and were invited to carefully analyze all of the varieties using each criterion.

According to their fitness to a specific evaluation criterion identified by all groups of farmers, each variety was given scores 1 through 5 (1, 2, 3, 4, and 5 represent very good, good, moderate, poor, and very poor, respectively), and sums and means of scores of each evaluation character of each variety were calculated. The overall value of each variety was calculated by multiplying the weight of the evaluation criterion by the mean of scores of each variety’s selection criteria across all criteria. Finally, the varieties were ordered according to their overall value for the final selection, with the least sum ranking first.

**2.6. Disease assessment**

The response of individual varieties to Anthracnose (Colletotrichum lindenmiuthianum) and web blight (Rhizoctonia solani) was evaluated through observation of the disease symptoms on different plant parts (leaves stem and pods). The information was gathered by using simple scaling from the evaluations undertaken on individual plots and the values for each plot were assigned using 1–9 scales as per CIAT (1987), with 1–3 indicating the absence of observable symptoms or a very small indication of the disease, resulting in little or no economic damage; 4–6 indicating the presence of observable and noticeable symptoms resulting in only insufficient economic injury, and 7–9 indicating severe to very severe symptoms resulting in significant yield loss or deduction. Based on the amount and extent of the symptoms observed, the varieties were classified into three groups as less susceptible (1–3), intermediate (4–6), and susceptible (7–9).

**2.7. Data analysis**

Data for individual locations were subjected to variance analysis using SAS. Test of homogeneity of error variance of the two locations was done through the application of the F test as per Gomez and Gomez (1984) and except the number of seeds per pod and grain yield per hectare, all other measured parameters showed homogeneous error variance. For measured parameters with homogeneous error variances, combined data analysis was performed, and for parameters with heterogeneous error variances, analysis of variance was performed separately for individual locations. The least significant difference (LSD) was
Dembele and Ashena searches have also shown significant differences at a 5% level of significance (DF) Days to Flowering; (NB) Number of branches per plant; (DM) Days to Maturity; (PH) Plant Height; (NPP) Number of Pods per plant; (HSW) hundred seeds weight.

Means with the same letters in the same column are not significantly different at a 5% level of significance; (DF) Days to Flowering; (NB) Number of branches per plant; (DM) Days to Maturity; (PH) Plant Height; (NPP) Number of Pods per plant; (HSW) hundred seeds weight.

### 3. Results and discussion

#### 3.1. Performance of evaluated common bean varieties

The results of the combined analysis of variance are presented in Table 3 and non-combined ANOVA for parameters with heterogeneous error variance is depicted in Table 7. The combined ANOVA revealed significant (P < 0.05) variation between the study materials for flowering days, maturity days, plant height, branch number/plant, pod number/plant, and 100 seed weight (Table 3). From Table 6, non-combined ANOVA for the number of seeds per pod and grain yield per hectare showed significant variation between the varieties at both locations. In both cases, the significant variation indicates the presence of genetic variation between the varieties and the attributes being studied. This genetic diversity is likely to be critical for the crop's future breeding programs, which will rely on phenotypic and molecular characterization of such genetic resources to generate new varieties. Daniel et al. (2014), Firew et al. (2012), and Gebre-Egziabher et al. (2014) all found significant variation between common bean varieties for the number of seeds per pod, number of pods per plant, hundred seed weight, and grain yield. Significant differences are also reported for days to maturity Gebre-Egziabher et al. (2014) and plant height (Daniel et al., 2014; Firew et al., 2012).

As presented in Table 3, days to flowering showed significant differences ranging from 50.83 to 63 days on average. Batu had an earlier flowering period while Awash-Melka and Mexican-142 had a delayed flowering period. Awash-1 and Awash-2 also flowered after the average value of the flowering period of 56.21 days. Results from previous researches have also shown significant differences for days to flowering (Dembele and Ashena hi, 2018; Firew et al., 2012).

Days to maturity resulted in significant variation and it ranged from 85.67-104.17 days (Table 3). Batu had the shortest maturity period while the varieties with the longest maturity period were Nazareth-2, Awash-Melka, and Awash 2 which recorded later maturity time than their average value of 97.5 days. Firew et al. (2012) reported that the maturity duration of common bean varieties ranged from 81.55 to 103.55 days.

The number of branches significantly differed between the tested varieties (Table 3). Mexican-142, Awash-Melka, and Awash-1 resulted in more branches than the mean value of 2.01. As the number of branches increases, it may have both positive and negative impacts on the crops’ productivity. As leaves compete for light and resources required to produce biomass, large numbers of branches may have a consequence that results in poor photosynthetic rate, reduced leaf area, and short stem length of the branches (Huilliu et al., 2014). In contrary to this, research findings on pigeon pea undertaken by Ram et al. (2016), as cited by Kandarkar et al. (2020), revealed that the number of primary branches showed a significant and positive correlation with grain yield that is used to improve the grain yield of pigeon pea. Furthermore, Kandarkar et al. (2020) also presented that the number of branches per plant showed the highest positive direct effect on grain yield which indicates that genotypes with a better number of branches will result in more amount of yield. The present study partially supports the above findings in that the varieties with more branches (Awash-Melka and Mexican-142) produced a better amount of grain yield, particularly at Simada.

The combined ANOVA also revealed a significant difference between the treatments for plant height (Table 3). The tallest plant height was obtained from Mexican-142. Awash-1, Awash-2, and Nazareth-2 also resulted in better plant height than the mean value (49.47 cm). Daniel et al. (2014) also reported Batu as the shortest variety. It was also reported that plant height varied considerably among bean varieties from 33 to 70 cm (Daniel et al., 2014) and 35.63–53.04 cm (Firew et al., 2012). According to Su et al. (2019), short plant height attributes to drought tolerance capacity that will lower the transpiration rate and ultimately reduce moisture stress during drought. But, under non-moisture stressed environments, tall plant height is important to produce better numbers of branches as well as more pods per plant. As to the present study, the varieties with high plant height produced more branches per plant and large numbers of pods per plant which contributes to a better amount of seed per plant. This result is supported by Al-Ballat and Al-Araby (2019) who reported that plant height is positively and significantly correlated with the number of pods per plant and seed yield per plant. Pod number/plant showed significant differences across treatments. Mexican-142, Awash-1, and Nazareth-2 produced a large number of pods per plant, whereas Batu and SAB-736 produced the least (Table 3). On the same crop, Dembele and Ashena hi (2018) and Gebre-Egziabher et al. (2014) obtained comparable results. Furthermore, Daniel et al. (2014) and Firew et al. (2012) discovered that the number of pods per plant differed greatly amongst common bean varieties, ranging from 9.3 to 19.33 pods and 10.05 to 21.29 pods, respectively. The combined ANOVA revealed significant variation between the varieties for hundred seeds weight, the same as it did for other plant metrics. The average hundred seed weight of the varieties ranged from 16.5 to 45 g, as shown in Table 3. Batu had the highest value, followed by SAB-736 while Mexican-142 showed the least value. The highest hundred seed weight of Batu and SAB736 varieties might probably be because of their relatively large seed sizes.

Combined ANOVA revealed a significant difference between locations for days to flowering, the number of branches per plant, days to maturity, plant height, and the number of pods per plant (Table 4). This suggested that the phenotypic performance of those features of
the varieties differed across the two locations, which could be due to environmental variation between them such as the unequal amount of rainfall, temperature change, and varying soil qualities. Hundred seed weight on the other hand showed non-significant variation between the two locations and is not influenced by changes in environmental conditions. The current significant disparity across locations for most plant characteristics is consistent with the findings of Dembele and Ashena (2018). Plant height, pod number/pod, seed number/pod, grain yield, and one hundred seed weight were also shown to change significantly between locations, according to Firew et al. (2012).

The combined analysis result of days to flowering was early at Libokemkem and late at Simada, as shown in Table 4. Libokemkem has a smaller number of branches than Simada. Plants reached physiological maturity in a short time at Libokemkem but took a long time at Simada. Simada had a tall plant height and a large mean number of primary branches. The current findings obtained by Daniel et al. (2014), Dembele and Ashena (2018), Firew et al. (2012), and Gebre-Egziabher et al. (2014), who reported a mean value ranging from 2.74 to 4.65 seeds per pod at Libokemkem and 3.9 to 6.35 seeds per pod at Simada. This result supports the findings obtained by Daniel et al. (2014), Dembele and Ashena (2018), Firew et al. (2012), and Gebre-Egziabher et al. (2014), who reported a mean value ranging from 4.0 to 6.83, 3.7 to 5.35, 3.51 to 5.27, and 5.33 to 7.43 seeds per pod, respectively. At Libokemkem, the highest number of seeds per pod was obtained from Awash-Melka followed by Mexican-142 while at Simada, the highest number of seeds per pod was produced from SAB-736. Awash-Melka, Batu, Awash-2, Mexican-142, and Awash-1 were high-yielding varieties at Simada with non-significant differences beetween them whereas SAB-736 and Nazareth-2 were low-yielding ones.

From the combined analysis of variance, the number of branches per plant and number of pods per plant showed significant differences due to the variety × location interaction, while days to flowering, days to maturity, plant height, and hundred seeds weight revealed non-significant differences (Table 5). The significant effect of the characteristics variety × location interaction revealed that the performance of the varieties was influenced by environmental variables in the two locations, resulting in performance inconsistency of common bean varieties across the two locations for such plant traits. This demonstrated the significance of testing the varieties in various places and seasons to ensure their stability for use as viable genetic materials for crop improvement and production in a particular region.

The non-significant variance owing to the variety × location interaction, on the other hand, may indicate that the varieties were not influenced by changes in environmental conditions for the attributes in question, resulting in consistent performance of the varieties across locations. Daniel et al. (2014) also found no significant differences in many attributes of popular bean varieties owing to variety × year. Dembele and Ashena (2018) also found substantial variation in the quantity of seed per pod for the treatment by location interaction, as well as non-significant differences in days to flowering and days to maturity, which is supported by the current study’s findings.

Mean square values for the number of seeds per pod and grain yield of the common bean as in Table 6. The combined analysis of days to flowering was early at Libokemkem and late at Simada, as shown in Table 4. Libokemkem has a smaller number of branches than Simada. Plants reached physiological maturity in a short time at Libokemkem but took a long time at Simada. Simada had a tall plant height and a large mean number of primary branches. The current findings obtained by Daniel et al. (2014), Dembele and Ashena (2018), Firew et al. (2012), and Gebre-Egziabher et al. (2014), who reported a mean value ranging from 4.0 to 6.83, 3.7 to 5.35, 3.51 to 5.27, and 5.33 to 7.43 seeds per pod, respectively. At Libokemkem, the highest number of seeds per pod was obtained from Awash-Melka followed by Mexican-142 while at Simada, the highest number of seeds per pod was produced from SAB-736. Awash-Melka consistently produced the highest number of seeds per pod across the two locations. Dembele and Ashena (2018) and Gebre-Egziabher et al. (2014) also stated that Awash-Melka produced the highest number of seeds per pod with a mean value of 7.43 and 5.77 seeds per pod, respectively. At individual locations, grain yield showed a significant difference between the studied varieties with mean values ranging from 842.5 to 1772.2 kg ha⁻¹ and 2467.5–3888.10 kg ha⁻¹ at Libokemkem and Simada, respectively (Table 7). At Libokemkem, the highest yield was obtained from Awash-2 followed by Awash-1 with no significant difference between the two, while the lowest yield was produced from SAB-736. Awash-Melka, Batu, Awash-2, Mexican-142, and Awash-1 were high-yielding varieties at Simada with non-significant differences between them whereas SAB-736 and Nazareth-2 were low-yielding ones.
This result is aligned with the findings stated by Daniel et al. (2014) and Firew et al. (2012), who discovered significant differences in grain production among common bean varieties. Dembele and Ashena (2018) and Gebre-Egziabher et al. (2014) did similar experiments on the same crop and found significant variation across the varieties, with values ranging from 1650 to 1900 kg ha⁻¹ and 1174–2129 kg ha⁻¹, respectively. In general, varieties responded better at Simada than at Libokemkem, which could be attributable to better environmental conditions during the growing season.

### 3.2. Farmers’ field evaluation and variety preference

Farmers examined selection criteria of the varieties and the findings are presented in Tables 7 and 8. The farmers employed seed shape, disease resistance, days to maturity, number of pods per plant, and number of seeds per pod as the variety evaluation and selection criteria. The farmers’ chosen criteria were prioritized using a pair-wise matrix ranking method. Disease resistance has the highest weight at Libokemkem (the higher the overall score, the more frequently favored by farmers as a selection criterion and placed first), followed by days to maturity and seed shape (Table 8), indicating that disease is the most important factor.

#### Table 8. Pair-wise ranking matrix of farmers’ evaluation and selection criteria at Libokemkem site, south Gondar zone in 2019 main cropping season.

| Evaluation Criteria | Seed shape | Disease resistance | DM | NPP | NSPP | Total score | Rank | Weight |
|---------------------|------------|--------------------|----|-----|-------|-------------|------|--------|
| Seed shape          | X          | Disease            | DM | Seed shape | Seed shape | 2 | 3 | 3 |
| Disease resistance | X          | Disease            | DM | Seed shape | Disease | 4 | 1 | 1 |
| DM                  | X          | DM                 | DM | DM | DM | 3 | 2 | 2 |
| NPP                 | X          | NPP                |     |     |     | 1 | 4 | 4 |
| NSPP                | X          |                   |     |     |     | 0 | 5 | 5 |

(DM) days to maturity, (NPP) number of pods per plant, (NSPP) number of seeds per pod.

#### Table 9. Pair-wise ranking matrix of farmers’ evaluation and selection criteria at Simada site, south Gondar zone in 2019 main cropping season.

| Evaluation Criteria | Seed shape | Disease resistance | DM | NPP | NSPP | Total score | Rank | Weight |
|---------------------|------------|--------------------|----|-----|-------|-------------|------|--------|
| Seed shape          | X          | Seed shape         | DM | NPP | NSPP | 2 | 3 | 3 |
| Disease             | X          | DM                 | NPP | NSPP | 0 | 5 | 5 |
| DM                  | X          | NPP                | NSPP |       | 1 | 4 | 4 |
| NPP                 | X          | NPP                |     |     |     | 4 | 1 | 1 |
| NSPP                | X          |                   |     |     |     | 3 | 2 | 2 |

(DM) days to maturity, (NPP) number of pods per plant, (NSPP) number of seeds per pod.

#### Table 10. Direct matrix ranking of white common bean varieties for the selected traits by the farmers at Libokemkem, South Gondar Zone, in the 2019 cropping season.

| Sn | Evaluation criteria | Weight of criteria | Mean of scores of white common bean varieties |
|----|---------------------|--------------------|---------------------------------------------|
|    |                     |                    | Awash-1 | Awash-2 | Awash-Melka | Mexican 142 | SAB 736 | Batu | Nazareth 2 |
| 1  | Seed shape          | 3                  | 1 (3)   | 1 (3)   | 2 (6)       | 1 (3)       | 4.25 (12.75) | 3.25 (9.75) | 1.75 (5.25) |
| 2  | DM                  | 2                  | 4 (8)   | 4.25 (8.5) | 3.75 (7.5) | 4.25 (8.5) | 1.75 (3.5) | 1 (2) | 4 (8) |
| 3  | NPP                 | 4                  | 2.5 (10) | 1 (4)   | 2 (8)      | 4 (16)    | 4.75 (19) | 5 (20) | 1.75 (7) |
| 4  | NSPP                | 5                  | 3.75 (18.75) | 1.25 (6.25) | 2.25 (11.25) | 3.25 (16.25) | 4.5 (22.5) | 5 (25) | 1.75 (8.75) |
| 5  | Disease reaction    | 1                  | 3 (3)   | 3.25 (3.25) | 1 (1)     | 2.5 (2.5) | 3.5 (3.5) | 4.5 (4.5) | 2.25 (2.25) |
| Sum of score        | 42.75         | 25                 | 33.75   | 46.25    | 61.25      | 61.25      | 31.25   |
| Overall rank        | 4              | 1                  | 3       | 5        | 7          | 6          | 2       |

Figures out of ( ) are mean scores given by farmers to each variety with each evaluation criteria; (1 = very good; 2 = good; 3 = moderate; 4 = poor and 5 = very poor) and numbers in ( ) are the product of the weight of the evaluation criterion and the mean scores of varieties.

#### Table 11. Direct matrix ranking of white common bean varieties for the selected traits by the farmers at Simada, South Gondar Zone, in the 2019 cropping season.

| Sn | Evaluation criteria | Weight of criteria | Mean of scores of white common bean varieties |
|----|---------------------|--------------------|---------------------------------------------|
|    |                     |                    | Awash-1 | Awash-2 | Awash-Melka | Mexican 142 | SAB 736 | Batu | Nazareth 2 |
| 1  | Seed shape          | 3                  | 1 (3)   | 1 (3)   | 3 (9)       | 1 (3)       | 4.75 (14.25) | 3.75 (11.25) | 2.25 (6.75) |
| 2  | DM                  | 4                  | 3 (12)  | 2.25 (9) | 3 (12)     | 1 (4)      | 3 (12)   | 3.25 (13) | 3.5 (14) |
| 3  | NPP                 | 1                  | 2.5 (2.5) | 2.75 (2.75) | 1.75 (1.75) | 1 (1)     | 4 (4)    | 4 (4)   | 3.25 (3.25) |
| 4  | NSPP                | 2                  | 2 (4)   | 1 (2)   | 1 (2)      | 3.5 (7)    | 4 (8)    | 4 (8)   | 3.25 (6.5) |
| 5  | Disease reaction    | 5                  | 1.25 (6.25) | 1 (5) | 2.75 (13.75) | 1 (3)     | 2.75 (13.75) | 1.25 (6.25) | 1.25 (6.25) |
| Total |                   |                     | 27.75   | 21.75   | 38.5       | 20        | 52       | 42.5    | 36.75   |
| Overall rank        | 3              | 2                  | 5       | 1        | 7          | 6          | 4       |

Figures out of ( ) are mean scores given by farmers to each variety with each evaluation criteria (1 = very good; 2 = good; 3 = moderate; 4 = poor and 5 = very poor) and numbers in ( ) are the product of the weight of the evaluation criterion and the mean scores of varieties.

This result is aligned with the findings stated by Daniel et al. (2014) and Firew et al. (2012), who discovered significant differences in grain production among common bean varieties. Dembele and Ashena (2018) and Gebre-Egziabher et al. (2014) did similar experiments on the same crop and found significant variation across the varieties, with values ranging from 1650 to 1900 kg ha⁻¹ and 1174–2129 kg ha⁻¹, respectively. In general, varieties responded better at Simada than at Libokemkem, which could be attributable to better environmental conditions during the growing season.
However, at Simada, farmers valued the number of pods per plant the most, followed by the number of seeds per pod and seed shape (Table 9), while disease resistance, which ranked first at Libokemkem, was not an essential selection criterion for the common bean varieties studied.

Farmers' preference ranking based on the aforementioned evaluation and selection criteria revealed that Awash-2, Nazareth-2, and Awash-Melka (Awash-2 is high yielder variety) were the best varieties at the Libokemkem site (Table 10). As shown in Table 11, the high producing varieties Mexican 142, Awash-2, and Awash-1 were also chosen as the best varieties at Simada by farmers' preference ranking. Based on the farmer's preference ranking, Awash-2 is the top-ranking variety followed by Nazareth-2 and Awash-Melka at Libokemkem. But, the top ranking of Nazareth-2 and Awash-Melka is not coinciding with the varieties' performance expressed in terms of grain yield. This disparity may bring difficulties for the adoption of the varieties by the farmers during seed distribution. This suggested that the need for evaluation and selection of the varieties not only at maturity period but also after harvest using grain yield as the variety evaluation and selection criterion. On the contrary, the varieties Mexican 142, Awash-2, and Awash-1 which are preferred and selected by the farmers at Simada are also high yielders and this synchronization is an important aspect for easy adoption of such varieties in the study area.

3.3. Disease response of the evaluated bean varieties

In terms of disease response, the varieties' responses to anthracnose and web blight showed slight variation. Batu, SAB7-36, Awash-Melka, Awash-2, and Awash-1 were categorized as less susceptible to Anthracnose at Libokemkem, while Mexican-142 and Nazareth-2 were categorized as intermediate. Except for Mexican 142, which had a very weak symptom, all of the other varieties at Simada had no obvious symptom, resulting in no economic loss. For both locations, the response of varieties to web blight was divided into two categories: less susceptible (1–3) and intermediate (4–6). Mexican-142, Batu, SAB736, Awash-Melka, and Nazareth-2 from the Libokemkem site, as well as all of the tested varieties from the Simada site, were found to be less susceptible (1–3). With a rating of 4, Awash-1 and Awash-2 from the Libokemkem site were classified as intermediate. When the two locations were compared, Libokemkem showed more disease symptoms than Simada, indicating that Libokemkem had more favorable environmental circumstances for pathogen growth.

4. Conclusion and recommendation

The genetic and environmental variations can cause a different level of response for the tested traits of the common bean. Testing of improved white common bean varieties at different locations is vital for assessing the performance and suitability of the varieties to be grown across agroecologies. The varieties with constant high-yielding characteristics are considered stable and better varieties which are appropriate for the improvement of crop productivity. Participatory variety evaluation and selection are also crucial for the easy adoption of improved white common bean varieties in new areas of production. A significant difference was observed among the studied white common bean varieties for grain yield, number of pods per plant, number of seeds per pod, one hundred seed weight, plant height, branch number per plant, days to maturity, and days to flowering. Analysis of variance revealed significant differences due to variety, location, and location-by-variety interaction that indicate the need for testing new varieties across locations and over seasons to assess their performance for yield and yield components in specific agroecologies. The study from the two locations showed that Awash-2 and Awash-1 at Libokemkem and Awash-Melka, Batu, Awash-2, Mexican-142, and Awash-1 at Simada were varieties with good potential in grain yield. But, only Awash-2 and Awash-1 revealed consistently higher yields than other varieties across the two locations. In addition to its better amount of grain yield, Awash-2 is also consistently preferred at both locations by the farmers during variety evaluation and selection at the field condition. Hence, Awash-2 needs to be promoted, multiplied, and distributed to the study areas and other varieties with good grain yield like Awash-1, Awash-Melka and Batu also need to be considered as the alternative varieties for the locations at which they performed well.

Declarations

Author contribution statement

Kassahun Amare: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Asmamaw Kassahun: Conceived and designed the experiments; Analyzed and interpreted the data.

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Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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