Evaluation of common bean varieties (*Phaseolus vulgaris* L.) to different row-spacing in Jimma, South Western Ethiopia

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**ARTICLE INFO**

**Keywords:** Agricultural science, Plant biology, Variety, Nasir, Goberesha, Local asendabo, Row spacing, Interaction

**ABSTRACT**

This study evaluated the effect of row spacing on growth, yield and yield components of common bean varieties at Jimma. The objectives of the study were (i) to evaluate the best performed common bean variety (ii) to determine the optimum row spacing for different common bean varieties under the test environment. The experiment was laid out in randomized complete block design (RCBD) in factorial arrangement with three replications. A combination of three common bean Varieties (Nasir, Goberesha and Local Asendabo) and row spacing at four levels (30, 40, 50, 60cm) were used as experimental treatments. Leaf number was significantly varied between the varieties; whereas row spacing significantly influence leaf area index. The main effect of row spacing and the interaction effect did not show significant influence on both. Hundred seed weight and number of seed per pod were varied between the varieties and row spacing. Hundred seed weight was increased with row spacing. Pod number per plant, nodule number per plant, grain yield and harvest index was significantly affected row spacing, variety and their interactions. Grain yields increased with plant population assuming a parabolic curve to the plant density of both determinate varieties at 40cm row spacing. The highest yield for variety-Nasir and variety-Goberesha were observed at40 cm row spacing; whereas the highest yield for the local variety was recorded at 50 cm row spacing.

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is the third most important food legume worldwide next to soybean and peanut (Singh, 1999). In terms of production area, Kenya is the largest common bean producer in Africa, and Ethiopia is the eighth largest producer in Africa (Ferris and Kagamzzi, 2008). It plays an important role in human nutrition and market economies of some rural and urban areas of Ethiopia (CSA, 2009). Common bean is an important pulse crop distributed and grown in different parts of Ethiopia (Tenaw, 1990). It is considered as the main cash crop and protein source of farmers in many lowlands and mid-altitude zones of the country, and is exported to earn foreign. Farmers prefer common bean because it's fast maturing characteristics that enable households to get cash income required to purchase food and other household needs when other crops have not yet matured (Legesse et al., 2006). The crop is grown as a sole crop and/or intercropped with cereal and/or perennial crops. Shade tolerance and early maturity contributes to the haricot beans intensification (Shimelis et al., 1990).

The common bean productivity is limited in Ethiopia with an average yield of 0.76 t ha⁻¹. Hence, more researches are required across different agro ecology zones to boost production.

Row spacing is vital to ensure maximum yield and avoid nutrient competition. Appropriate spacing enables the farmer to keep appropriate plant population in his field. Hence, a farmer can avoid over and less population in a given plot of land, which has negative effect on yield (Mulugeta, 2011).

Spacing was introduced to the study area to improve food security. Despite several interventions have been made to boost haricot bean production, adoption of improved production package is still limited in the country. Moreover, there is also variation among farmers in their intensity of adoption of improved haricot bean production package (Rahmeto, 2007).

Moreover, in the study area there is a trend by farmers to use local variety and higher seed rates as they have increased the rate of fertilizer use. Thus, it is essential to evaluate the best performed varieties with their optimum plant population for newly developed common bean varieties for getting the maximum yield. So the present study was therefore initiated to accomplish the following specific objectives.

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https://doi.org/10.1016/j.heliyon.2020.e04822

Received 9 January 2020; Received in revised form 8 April 2020; Accepted 26 August 2020

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To evaluate the best performed common bean variety and their optimum row spacing under the test environment
To determine the influence of row spacing on yield and yield components of common bean varieties

2. Material and methods

2.1. Description of the experimental site

The field experiment was conducted at Jimma Mana woreda during 2017/18 by rain which is located at 7°40' N latitude and 36° E longitudes at an elevation of 1753 m a.s.l. The soil type of the experimental area is Eutric Nitsols (Reddish brown) and had a pH of around 5.1 (Table 1). The mean annual rainfall of the area is 1639 mm with a maximum and minimum temperature of 26.6 °C and 13.9 °C, respectively.

2.2. Treatments and experimental design

Table 2 illustrates factorial combination of three varieties and four inter row spacing. The experiment was laid out in RCBD with three replications.

2.3. Experimental procedures and crop management

Land preparation was done in early July 2016 and ploughed with oxen and hand leveled before sowing. Common bean varieties were sown in mid-July by row planting and was covered by hand on the gross plot oxen and hand leveled before sowing. Common bean varieties were sown by putting two seeds with 10cm intra row spacing and 30, 40, 4.8 m length was used. The outermost rows at both sides of plots were considered as borders. A 1.5 m wide-open strip separated the blocks; the mean rainfall of the area is 1639 mm with a maximum and minimum temperature of 26.6 °C and 13.9 °C, respectively.

2.4. Data collected

Plants used for the data collection were randomly selected, tagged and all the data were recorded from them.

Leaf number: leaf numbers were taken from five randomly selected plants at 50% flowering by counting all the leaf from the base to the tip of the plant in each plot.

Nodule number per plant: were collected at 50% flowering date from the same five plants by uprooting the plants carefully and counting their nodules.

Leaf area index: In the same manner with other traits leaf area index were collected from the same plant randomly selected and determined by measuring five plants canopy in each plot and dividing leaf area by their canopy.

Number of pods per plant: These were taken from the same five randomly selected tagged plants at the end of harvest in each plot and the number of pods were counted and recorded carefully.

Number of seed per pod: From the same five randomly selected and tagged plants ten pods were randomly collected from the bottom mid and upper part of the plants during harvesting time and these pods were trashed individually and numbers of seed per pod were counted carefully from each plot.

100 Seed weight: The seeds were counted using electronic seed counter from a sample of threshed seeds from each plot and measured by sensitive balance at 12.5% moisture content.

Yield: Bean yield were trashed, measured from the net plot area of the harvestable row (at the middle rows without border effect) and expressed as kg ha⁻¹. Bean yield were adjusted to 12.5% moisture using a digital moisture tester.

Harvest Index: Was calculated as the ratio of economic yield (grain yield) of harvestable row to biological yield of harvestable row multiplied by 100.

2.5. Statistical data analysis

Data were subjected to analysis of variance (ANOVA) using (Gen Stat version 13). Significance differences between treatment means were delineated using Least Significance Difference (LSD) test at 5% probability level.

3. Results and discussion

Leaf number: was varied significantly (P < 0.05) between the varieties. The local variety had the highest leaf number (37). The higher leaf number of the Local variety might be from the genetic make-up of the variety or vigorous in nature (Table 2 variety description). The variety which has higher leaf number is indeterminate type that makes it to climb nearby plant and has longer in nature. Because of its length there were higher in leaf number per plant. But, the main effect of row spacing and the interaction effect of the main effects of variety and row spacing did not indicate significant difference (Table 3). But numerically when we observe number of plant per unit area, leaf number increased with decreasing population density. This shows the sink limitations to photosynthesis due to plant competition for resources.

Leaf Area Index: This result evidenced that, the main effect of row spacing noticed significant (P < 0.05) variation; where us, the main effect of variety and the interaction effect specified non-significant difference on leaf area index. As indicated in the result (Table 3) the higher leaf area index was recorded when the distance between rows decreased and the lower was when the distance between rows increased. Non-significant variation had observed between 30 and 40 cm row spacing and this was where higher leaf area index was observed. The lower leaf area index was seen on the longer spaced rows of 50 and 60cm. There is no significant variation in between this 50 and 60cm row spaces. The increment of leaf area index on shorter spaced row of the common bean might be from the increased number of plants per unit area contributing more number

Table 1. Major characteristics of the soil of study area before sowing.

| Soil Parameters          | Values |
|-------------------------|--------|
| Total Nitrogen (%)      | 1.74   |
| pH (H2O, KCl)           | 5.10   |
| Organic carbon (%)      | 2.22   |
| Organic matter (%)      | 3.83   |
| Available phosphorus (ppm Bray II) | 0.26 |
| Available potassium (meq K/100g) | 2.11 |
of leaves in that given space. This result corroborates with the findings of Franc and Martina (2001); Bruns and Abbas (2003); Mohammed et al. (2012) who have confirmed that the LAI is increased as spacing decreased and decreased as spacing increased.

Nodule number per plant: As observed form Table 4, nodule number showed highly significant (P < 0.01) difference due to the interaction effect of the main effect of common bean variety and row spacing. Higher nodule number was observed when nasir and goberesha variety was sown with 30cm row spacing and the lower was observed when local variety was sown with 60cm row spacing. This might resulted from the common bean variety genotype to the narrow row spacing. It was observed that, as row spacing increased; number of nodules per plant decreased.

Table 2. Factorial combination of three varieties and four inter row spacing.

| Treatments                  | description                                                                 |
|-----------------------------|-----------------------------------------------------------------------------|
| Varieties                   |                                                                             |
| V1 (Nasir)                  | Vine(bushy), small in size, red to brown color                              |
| V2(Goberesha)               | Vine(bushy), large in size red to brown                                     |
| V3(Local Asendabo)          | Climber, Large in size, white                                              |
| Row-Spacing                 |                                                                             |
| 30cm inter row spacing*10 cm intra row spacing | 333,330 plants/ha              |
| 40cm inter row spacing *10cm intra row spacing | 250,000 plants/ha              |
| 50cm inter row spacing *10cm intra row spacing | 200,000 plants/ha              |
| 60cm inter row spacing *10cm intra row spacing | 166,000 plants/ha              |

Table 3. The main effect of variety and Row spacing on common bean Leaf number, hundred seed weight, number of seed per pod and leaf area index.

| Source of variation | Leaf number per plant | Hundred seed weight | Number of seed per pod | Leaf Area Index |
|---------------------|-----------------------|---------------------|------------------------|-----------------|
| Common bean Variety |                       |                     |                        |                 |
| Nasir               | 21.23<sup>b</sup>     | 48.82<sup>b</sup>   | 3.74<sup>b</sup>       | 3.61            |
| Goberesha           | 20.92<sup>b</sup>     | 49.24<sup>b</sup>   | 3.87<sup>b</sup>       | 3.94            |
| Local Asendabo      | 37.39<sup>a</sup>     | 89.21<sup>a</sup>   | 4.56<sup>a</sup>       | 3.61            |
| SEM (±)             | 1.10                  | 2.28                | 0.31                   | 0.19            |
| P value             | <.001                 | <.001               | 0.03                   | NS              |
| Row spacing (cm)    |                       |                     |                        |                 |
| 30                  | 24.40                 | 54.79<sup>b</sup>   | 3.38<sup>b</sup>       | 4.14<sup>a</sup>|
| 40                  | 26.11                 | 64.26<sup>b</sup>   | 4.17<sup>b</sup>       | 4.03<sup>a</sup>|
| 50                  | 26.50                 | 64.31<sup>a</sup>   | 4.37<sup>a</sup>       | 3.36<sup>a</sup>|
| 60                  | 29.05                 | 66.32<sup>a</sup>   | 4.31<sup>a</sup>       | 3.36<sup>a</sup>|
| SEM (±)             | 1.27                  | 2.64                | 0.35                   | 0.22            |
| P value             | NS                    | 0.02                | 0.04                   | 0.02            |
| Cv (%)              | 14.4                  | 12.7                | 18.4                   | 17.4            |

Means followed by the same letter within a column are not significantly different from each Other, LSD = Least Significant Difference, CV = Coefficient of Variation, SEM = Standard Error of Mean.

Table 4. Effect of variety and row spacing interaction on common bean number of pod per plant, Number of nodule per plant and grain weight (kg/ha).

| Source of variation | Number of pods per plant | Nodule number per plant | Grain weight (kg/ha) | Harvest Index |
|---------------------|--------------------------|-------------------------|----------------------|---------------|
| Common Bean Variety* |                          |                         |                      |               |
| Row spacing         |                          |                         |                      |               |
| N*30cm              | 14.57<sup>de</sup>      | 38.33<sup>c</sup>      | 1635<sup>b</sup>     | 64.22<sup>a</sup>|
| N*40 cm             | 21.28<sup>b</sup>       | 29.67<sup>d</sup>      | 2236<sup>d</sup>     | 74.25<sup>b</sup>|
| N*50 cm             | 18.67<sup>de</sup>      | 23.67<sup>c</sup>      | 1533<sup>b</sup>     | 60.70<sup>c</sup>|
| N*60 cm             | 29.33<sup>b</sup>       | 27.67<sup>b</sup>      | 2007<sup>d</sup>     | 72.29<sup>d</sup>|
| G*30 cm             | 19.76<sup>c</sup>       | 22.33<sup>c</sup>      | 1591<sup>bc</sup>    | 61.72<sup>bc</sup>|
| G*40 cm             | 20.33<sup>b</sup>       | 27.67<sup>b</sup>      | 2007<sup>d</sup>     | 72.29<sup>d</sup>|
| G*50 cm             | 19.76<sup>c</sup>       | 22.33<sup>c</sup>      | 1591<sup>bc</sup>    | 61.72<sup>bc</sup>|
| G*60 cm             | 16.57<sup>b</sup>       | 20.33<sup>b</sup>      | 1397<sup>cd</sup>    | 52.85<sup>d</sup>|
| L*30 cm             | 11.80<sup>ef</sup>      | 14.00<sup>ef</sup>     | 1075<sup>d</sup>     | 36.75<sup>d</sup>|
| L*40 cm             | 13.07<sup>ef</sup>      | 12.33<sup>ef</sup>     | 1117<sup>d</sup>     | 48.75<sup>c</sup>|
| L*50 cm             | 17.20<sup>bc</sup>      | 10.00<sup>ef</sup>     | 1632<sup>bc</sup>    | 60.02<sup>d</sup>|
| L*60 cm             | 27.00<sup>a</sup>       | 6.00<sup>ef</sup>      | 1549<sup>d</sup>     | 51.49<sup>d</sup>|
| SEM ±               | 1.71                    | 0.99                   | 1.25                 | 1.71           |
| P value             | 0.002                   | <.001                  | <.001                | <.001          |
| Cv (%)              | 16.8                    | 7.9                    | 13.8                 | 5.1            |

Means followed by the same letter within a column are not significantly different from each Other, LSD = Least Significant Difference, CV = Coefficient of Variation, SEM = Standard Error of Mean, N =Nasir, G = Goberesha L = Local Asendabo.
decreased in all interaction (Table 4). When row spacing increased competition in between plant will be minimized; because, enough space can be found in between the rows and available nutrients can be easily taken by the root of plants. This might enforced them to fail to bear nodule; so, the number of nodule could be minimized. This result disagrees with what Shamsi and Kobraee (2012) observed. They stated that, at lower plant densities the photosynthetic rate per plant increased and, consequently, higher carbon (C) supplied to the nodules resulted in an increase in nodulation and in nitrogen fixation rates. Kapustka and Wilson (1990) also found out that, an increase in soybean plant density reduced nodule number. The lower nodule per plant for local variety interaction with row spacing in compare with nasir and goberesha interaction with all tested row spacing might be from nature of the variety. Also Kouyate et al. (2012) reported, variety can affect nodule number.

**Number of pods per plant:** The interaction of bean variety and row spacing as well as the main effect of row spacing revealed significant (P < 0.05) difference on number of pod per plant. The higher number of pod per plant was recorded when local bean variety sown with 60cm row spacing and the lower was obtained when goberesha common bean variety sown with 30cm row spacing. The indeterminate nature of local common bean, the wider row spacing of crops and the lower competition between the plants might be initiated the pod bearing per plant. But, we cannot say increased number of pod per plant can be increase yield per hectare; because total yield is determined by the yield harvested from individual plant and number of plants per hectare in addition to variety selection. When we observed individual varieties higher pod number per plant across all treatment interaction with row spacing; nasir variety gave the higher pod number per plant when sown with 40cm, goberesha when sown with 40cm and local variety when sown with 60cm row spacing. Tamado et al. (2007) and Masa et al. (2017) reported that, number of pods per plant was significantly affected by row spacing and variety. Turk et al. (2003) also confirmed as the number of pods per plant positively related to row spacing.

**Number of seed per pod:** Both main effects indicated significant (P < 0.05) difference on number of seed per pod and interaction effect indicated non-significant effect. Among the varieties; local common bean showed higher number of seed per pod; however, nasir and goberesha varieties showed the lower. This could be form the inherent variation in the genetic makeup for photosynthesis and translocation of dry matter to grain yield production. The lower number of seed per pod was seen on shorter spaced rows of 30cm and the higher was on 50cm row spacing. But non-significant variation was seen in between 40, 50 and 60cm row spacing. Competition of crops for solar radiation and nutrients due to smaller space in between rows could be the case for the lower seed number per pod. Mitiku and Getachew (2017) found that number of seed per pod had increased as row spacing increased and decreased as row spacing decreased.

**Hundred seed weight (gm):** As indicated in Table 3 the main effect of variety indicated highly significant (P < 0.01), while the main effect of row spacing was significant (P < 0.05) on hundred seed weight; however, their interaction effect showed non-significant variation. Among the varieties the local bean showed the higher hundred seed weight. This might be from the vigorous nature of the local common bean variety seed genotype. Masa et al. (2017) found significant difference on the hundred seed weight due to different bean genotypes. Tamado et al. (2007) also found that, hundred seed weight was significantly different between varieties; hundred seed weight was increased with increase in row spacing. That might be due to enough growth resource availability under wider row spacing which converted biological yield to economic yield and stored in seed yield. In addition, in wider spaced plants, improved supply of assimilates to be stored in the seed, hence, the weight of hundred seeds increased. Masa et al. (2017) expressed that 100 seed weight increased with increasing in row spacing. Similarly Dahrmardeh et al. (2010) said spacing significantly (P < 0.05) affects been hundred seed weight.

**Yield kg/hectare (Grain weight):** Result revealed that grain weight was highly significantly (P < 0.01) affected by the main effects of variety and row spacing and the interaction effects of the main effects. The higher grain yield was obtained when nasir and goberesha common bean variety sown in interaction with 40cm row spacing and the lower was found when local bean sown with 30cm row spacing. In this interaction; nasir and goberesha variety grain yield was increased with increasing row spacing up to 40cm and then starts to decline on 50cm-60cm row spacing. That means; grain yield increased with increase in row spacing up to 40cm assuming a parabolic curve to the crop variety, with higher yield for both determinate varieties of Nasir and Goberesha. This higher yield on both varieties occurred because of optimum row spacing for this variety and probably due to more efficient utilization of available resources without competing with each other and enough space for well management of the crop. But as row spacing increased the yield of the local variety increased up to 50cm row spacing and starts to decline on 60cm. This local variety gave the higher grain yield on wider row spacing 50 and 60cm in compare to closer row spacing of 30 and 40cm. Local common bean which has the nature of coiling and climbing nearby crop or tree intertwined and combined together at 30 and 40cm. This nature might influence the penetration of solar radiation to reach the plant and initiate photosynthesis process. In addition yield reduction of local variety at narrower row spacing could be due to interplant competition for resources such as nutrients, water and solar radiation. The result found by Birhanu et al. (2018) confirmed that the adverse effect on the yield of mung bean was noticed which might be due to intense interplant competition and floral abortion caused from narrower spacing. Similarly, Dahrmardeh et al. (2010) reported that, decreased row spacing of faba bean increased plant population; that has been the case for an increase in competition between plants for light reception and nutrient.

**Harvest Index:** Highly significant (P < 0.01) difference was indicated on harvest index due to the main effect of variety and row spacing and due to their interaction effect. The higher harvest index was observed when nasir and goberesha variety sown with 40cm row spacing and the lower was recorded when local variety sown with 30 cm row spacing. As it can be observed from the result Table 4, the one that gave higher and lower common bean yield indicated higher and lower harvest index respectively. Higher result could be from the optimum plant row spacing of the variety that leads to give higher harvest index and the lower could be from shorter row spacing and from the nature of the variety to the specific row spacing. Birhanu et al. (2018) and Khan et al. (2010) also found significant variation on harvest index of mung bean due to row spacing.

4. Conclusion

This study indicated that, the row spacing and variety as well as the interaction of both row spacing and variety influences the yield and yield components of common bean. Practicing the appropriate row spacing and variety selection can increase the economic yield of common bean. The higher yield 2236 and 2007 kg/ha was obtained from Nasir and Goberesha variety respectively when sown with 40cm row spacing. However, as row spacing increased yield of Nasir and Goberesha variety had increased up to 40cm row spacing. But at 50 and 60cm row spacing they started to decline. The local cultivar showed higher yield of 1632 kg/ha on treatment sown with 50cm row spacing. But, as row spacing of local cultivar increased the yield was increased up to 50cm then it showed declination on 60cm. In addition, grain yield depends on the type of variety. As a general Nasir and Goberesha variety performed better at 40cm row spacing and local variety at 50cm row spacing. Even if giving persuasive recommendation is difficult by one season experiment in a single location; the best performed common bean variety by this single trail is nasir variety with 40cm row spacing. So, for this finding multi locational experiment in more than one season can give valuable recommendation.
Declarations

Author contribution statement

Jibril Temesgen Merga: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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