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# Influence of Plant Spacing and Phosphorus Rates on Yield Related Traits and Yield of Faba Bean *(Viacia faba L.) in Duna District Hadiya Zone, South Ethiopia*

**Teklu Hailu***
Lecturer and Researcher at Department of Plant Science, College of Agriculture and Natural Resources, Mizan-Tepi University, Ethiopia

**Solomon Ayle**
Lecturer and Researcher at Department of Soil Science, College of Agriculture and Natural Resources, Mizan-Tepi University, Mizan Teferi, Ethiopia

## Abstract

A field experiment was conducted to study the effects of plant spacing and phosphorus rates on yield related traits and yield of faba bean (Viacia faba L.) at Farmers Training Center, Duna District during 2015 summer cropping season. Three intra-rows spacing (5, 10 and 15 cm), three inter-rows spacing (30, 40 and 50 cm) and three phosphorus rates (0, 46 and 92 kg/ha) were tested. The experiment was laid out as a randomized complete block design (RCBD) and was replicated three times. Improved faba bean variety (Degaga) was ued as test crop. Phenological growth parameters yield and yield related data were collected and their ANOVA was analyzed using GenSta 5$^{th}$ edition and while treatment means were significantly different, they were separated using Least Significant Difference (LSD) at 5% probability level. There was highly significant (P<0.01) effect of the highest rate of phosphorus (92 kg $P_2O_5$ ha$^{-1}$) on days to flowering, days to maturity, leaf area index, effective nodules per plant, plant height , primary tillers plant$^{-1}$, seeds pod$^{-1}$, hundred seed weight, grain yield, above ground dry biomass and harvest index. Significantly lowest days to flowering (54.3 days) after emergence and highest plant height (105.63 cm), leaf area (1073 cm$^2$), seeds pod$^{-1}$(3.57), grain yield (2633 kg ha$^{-1}$), dry biomass (8108kg ha$^{-1}$) and harvest index (32.47) were obtained from the highest rate of P (92 kg $P_2O_5$ ha$^{-1}$). For all inter-rows spacing, the leaf area, number of primary tillers, pods plant$^{-1}$, seeds pod$^{-1}$ and hundred seed weight were increased as intra-row spacing increase and the highest leaf area (1084 cm$^2$), primary tillers (2.99) and hundred seed weight (54.59 g) were obtained from the widest (50 cm) inter-row spacing, while the highest effective nodules (59.56) and leaf area index (3.51) were resulted from the narrowest (30 cm) inter-row spacing. On the other hand, the interaction effects of inter and intra-row spacing significantly influenced, number of pods plant$^{-1}$, number of seeds pod$^{-1}$, above ground dry biomass, grain yield and harvest index. The 30 cm inter-row by 15 cm intra-row spacing gave the highest grain yield (2495 kg ha$^{-1}$), harvest index (35.79%) and pods plant$^{-1}$(19.68) whereas the highest dry biomass (8738 kg ha$^{-1}$) was obtained from 30 cm x 5 cm spacing combination. Thus, it can be concluded that application of 92 kg $P_2O_5$ ha$^{-1}$ rate of phosphorus at 30 x 15 cm spacing combination proved to be superior with respect to grain yield in the study area. However, further study at least for one more cropping season under different soils is required to reach at conclusive recommendation.

**Keywords:** Faba bean; Inter-row spacing; Intra-row spacing; Phosphorus; Yield.



## 1. Introduction

Faba bean (*Vicia faba* L.) is one of the oldest domesticated food legume has been cultivated for at least 500 years. Its exact geographical origin is unknown, although Central Asia and Mediterranean region has been proposed as possible center [1]. Present wild species are similar in appearance to the cultivated plant but genetic analyses shown that the wild types have a different number of chromosomes. Field trials to cross the wild and cultivated species have been unsuccessful [2]. Faba bean is most likely introduced to Ethiopia from Middle East soon after domestication through Egypt around the 5$^{th}$ millennium B.C [3].

According to the united Nations Food and Agriculture Organization [4], China is currently the world's leading producer accounts for approximately 60% of the total production. Other important production regions are northern Europe, the Mediterranean, the Nile Valley, Ethiopia, Central and East Asia, and the Americans.

Faba bean is an annual herbaceous plant with coarse hollow stems that can reach height of two meters. It has pinnate leaves, consisting of two to six leaflets. It is mainly pollinate by bumblebees. White flowers with purple markings form in clusters of one to five, and one to four pods usually developed from each flower cluster. Up to 30 cm in height, each pod contains from three to twelve seeds. The plant also has a thick taproot up to one meter with abundant lateral roots [5]. Faba bean require a cool season and for best growth and are usually planted asa winter annual in subtropical or warm temperate regions. It can tolerate a wide range of soil types and pH but grow best in loamy soils. It requires moderate amount of water. Depending on the growing and environmental conditions, it takes about four or five months for the pods to mature enough for the seeds to be harvested [6, 7].

Ethiopia is probably one of the primary centers of diversification for faba bean. Although the small-seeded Ethiopian Faba bean is not well studied, there are some reports tremendous in protein content and disease resistance.

*Corresponding Author

Faba bean is produced in many regions of Ethiopia. The major producing regions are Tigray, Gojam, Gondar, South Region Wollega, Wollo, Gamo Gofa and Shoa. In addition, it is grown in the pockets in the rest of the country's highland and semi-highland regions with altitudes ranging from 1800 to 3000 m above sea level. Currently, the total area under cultivation is estimated to be 538,458 ha of land from which 8,907,632quintals are produced [8]. Faba bean is widely used for food and have high protein content. Due to its atmospheric nitrogen fixing capacity, it is used as crop rotation with the nationally important cereal crops like wheat, teff, barley and maize. Due to long cropping history and low manure and fertilizer inputs, the nutrient status of Ethiopian soils is generally low and phosphorus is the most limiting nutrient in faba bean producing areas including the experimental site. Even if Southern region of Ethiopia is one of the major producing areas in faba bean, there is no awareness on proper plant population and phosphorus application that is important to increase faba bean production and productivity in Duna district. Therefore, the aim of this study was to assess the effect of plant spacing and phosphorus fertilizer rates on yield related traits and yield of faba bean.

# 2. Materials and Methods

## 2.1. Description of the Study Area

The study area is located in South Nations, Nationalities and Peoples Regional State; Hadiya zone at Duna wereda. The experimental site is located at about 175 km to southwest direction of Hawassa town, Capital City of the Regional State. The altitude of the experimental site ranges from 2670 to 2930 m above mean sea level. Its geographical location is 7°3'19'N latitude and 37°23'14'E longitude. The mean maximum and minimum temperature of the experimental site is 26.70 and 9.80°C, respectively and the mean annual rainfall in the area is about 1150 mm, which is erratic and uneven in distribution [9].

## 2.2. Experimental Materials

Three phosphorus rates (0, 46 and 92 kg/ha), three inter-rows (30, 40 and 50 cm) and three intra-rows spacing (5, 10 and 15 cm) were used in the study in 2015 main cropping season. Degage improved variety was used as a test crop, which was released by Holetta Agricultural Research Center National Seed Trial in 2002**.**

## 2.3. Experimental Design

The experimental design was randomized complete block design (RCBD) with three replications. The respective rows for 30, 40 and 50 cm were 8, 6 and 5. The gross plot size was 5 $m^2$and the distance between plots and replications were 1 and 1.5 m, respectively. Date of planting was made in July 14, 2015. Urea (46 kg/ha) was applied at planting as starter. Weeding and other agronomic practices were carried out as per recommendation for the crop. Neither herbicides nor insecticides were applied. Three middle rows were harvested, dried, threshed and cleaned for data collection.

## 2.4. Crop Data Collection

### 2.4.1. Phenological Parameters

Days to 50% flowering: was recorded as the number of days from planting to when 50% of the plants produced flower through visual observation

Days to 90% physiological maturity: was recorded as the number of days from planting to when the plants attained 90% physiological maturity i.e. when the plants and the pods turned pale yellow in color based on visual observation.

### 2.4.2. Growth and Growth Related Parameters

Leaf area index: was calculated as the ratio of total leaf area per area of land ($cm^2$) occupied by the plant, i.e. LAI = TLA/LA Where: LAI = Leaf area index, TLA = Total leaf area per plant and LA = Area of the land occupied by the plant

Plant height (cm): from the net plot area, the height of five randomly tagged plants was measured from ground to the tip (apical bud) and the averages were recorded as plant height at physiological maturity stage

Number of primary tillers per plant: was taken by counting the number of primary tillers from the main stem from randomly taken five plants at physiological maturity

### 2.4.3. Yield Components and Yield

Number of pods per plant: was recorded by counting the number of pods from randomly tagged five plants and their average was taken as number of pods per plant at harvest

Number of seeds per pod: after pods were counted from each of the five randomly selected non-border plants/net plot area, seeds were hulled to get the number of seeds per pod. For each plant, the average number of seeds per pod was calculated by dividing the total number of seeds by the number of pods per plant

Above ground dry biomass yield (kg $ha^{-1}$): at maturity, plants from the central rows of a net plot area were manually harvested close to the ground surface using a sickle. The harvested plants were sun-dried in the open air until constant weight retained and weighed to determine the above ground dry biomass

Harvest Index: was calculated as the ratio of grain yield to the total above ground dry biomass [10].

Grain yield (kg $ha^{-1}$): was measured from the net plot area. Grain yield was cleaned following harvesting and threshing, weighted using an electronic balance and adjusted to 12.5% moisture content according to Kindie [11] model. Finally, yield per plot was converted to per hectare basis.

Hundred seed weight (g): this parameter was determined based on the weight of 100 seeds randomly sampled from the seed lots of each treatment by counting manually and weighing by an electronic balance

### 2.5. Statistical Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in randomized complete block design (RCBD) according to the General Linear Model (GLM) of GenStat $15^{th}$ edition GenStat [12] and the interpretations were made following the procedure described by Gomez and Gomez [13]. Least Significance Difference (LSD) test at 5% probability level was used for mean comparison when the ANOVA showed significant differences.

## 3. Results and Discussion

### 3.1. Phenological Parameters

### 3.1.1. Days to 50 % Flowering

The main effects of phosphorus, inter- and intra- row spacing were highly significant (P<0.01) effect on days to 50% flowering (Table 1). Significantly highest days to 50% flowering (57.89 days) were recorded at the control plots whereas the lowest (54.3 days) was recorded due to 92 kg $P_2O_5ha^{-1}$ application (Table 1). This is due to the fact that phosphorus fertilizer enhance flowering. Photosynthesis and assimilate partitioning of crop from source to sink is mainly determined by the ability of crop to utilize phosphorus [10]. In line with this result, Turk and Tawaha [14] reported that P application was increased crop development rate resulted in decreasing the number of days to 50% flowering of faba bean compared to control plots.

Days to flowering were significantly decreased as inter row spacing increased from 30 to 40 cm. This might be due to the fact that at wider inter rows (40 and 50 cm) had a better light interception as compared to the narrower spacing resulted in less number of days to flower as faba bean needs direct sunlight coverage for its various physiological processes. Also days to flowering was enhanced as intra-row spacing increased from 10 to 15 cm. This might be more nutritional area available in wider intra- row spacing might have caused the crop to flower earlier than the closer spacing. Meanwhile, in narrower intra- row spacing due to competition for light, nutrients, moisture and space, the crop revealed delayed flowering as intra-row spacing decreased. Similar to this result, Farag and El-Shamm [15] reported that the wider plant spacing of 50 cm reduced number of days to flowering in broad bean as compared to 40 cm plant spacing. In contrast, Turk, *et al.* [16] found that the denser plant population hastened days to flowering in lentil.

### 3.1.2. Days to 90% Physiological Maturity

The number of days to 90% physiological maturity was highly and significantly (P<0.01) affected by the main effects of phosphorus, inter-and intra-row spacing (Table 1). Significant variations were found among the different rates of phosphorus usage for physiological maturity period in faba bean. Applying P fertilizer significantly enhanced days to physiological maturity. The highest number of days required for completion of growth period of faba bean (136.3 days) was recorded due to no P (0 kg $P_2O_5ha^{-1}$) application rate while the highest phosphorus fertilizer rate showed the lowest growth period of physiological maturity (133.9 days) (Table 3). This could be due to the fact that phosphorus fertilization enhanced the physiological maturity of plants. Similar to the present results, hastening crop maturity due to increasing phosphorus supply was also reported by Brady and Weil [17]. Halvin, *et al.* [18] also indicated that ample phosphorus nutrition could reduce the time required for grain ripening. With respect to the main effects of inter and intra-row spacing, the narrowest inter row spacing (30 cm) took 136.1 days to attain physiological maturity which was significantly enhanced by wider spacing of 40 and 50 cm (Table 1).

Similar trend was observed due to intra-row spacing. The prolonged days to maturity with narrower inter and intra-row spacing might be due to high competition for the available resource that prolonged maturity. In addition, light would be intercepted better in the wider inter and intra- rows spacing relative to the narrower inter and intra-row spacing and also the better free air circulation in the canopy of the wider spaced rows could have its own contribution for shorter days to maturity. In line with this result, Hodgson and Blackman [19] reported that narrower row spacing and plant spacing prolonged maturity days of faba bean compared to wider spaced crops. Similarly, Oad, *et al.* [20] reported that the closer row and plant spacing delayed maturity days of sunflower as compared to wider spacing.

**Table-1.** Main effects of phosphorus rates, inter and intra-row spacing on days to 50% flowering and days to 90% maturity of faba bean

| Treatment | Days to 50 flowering | Days to 90% maturity |
|---|---|---|
| Phosphorus levels (kg $P_2OP_5$ ha$^{-1}$) | | |
| 0 | 57.89$^c$ | 136.3$^c$ |
| 46 | 55.6$^b$ | 134.1$^a$ |
| 92 | 54.3$^a$ | 133.9$^a$ |
| LSD (0.05) = | 0.741 | 0.912 |
| Inter-row spacing (cm) | | |
| 30 | 57.48$^c$ | 136.1$^c$ |
| 40 | 56.04$^a$ | 134.7$^b$ |
| 50 | 55.96$^a$ | 132.4$^a$ |
| LSD (0.05) = | 0.639 | 0.808 |
| Intra row-spacing (cm) | | |
| 5 | 57.26$^b$ | 135.5$^c$ |
| 10 | 56.63$^b$ | 134.7$^b$ |
| 15 | 54.59$^a$ | 133.1$^a$ |
| LSD (0.05) = | 0.833 | 0.962 |
| CV (%) = | 2.4 | 1.2 |
| Mean values within column followed the same letter (s) are not significantly different, LSD = Least Significant Difference at 5% level; CV= Coefficient of Variation | | |

## 3.2. Growth and Growth Related Parameters

### 3.2.1. Leaf area Index

The main effects of phosphorus, inter and intra-row spacing indicated that highly significant ($P<0.01$) effect on leaf area index (Table 2). The highest leaf area index (3.13) was recorded at the highest rate of P (92 kg $P_2O_5$ ha$^{-1}$) which was statistically similar with leaf area index (LAI) obtained due to 46 kg $P_2O_5$ ha$^{-1}$ rate of P application whereas significantly lowest (2.8) LAI was recorded with control plots (Table 2). The highest physiological growth indices are achieved under high plant nutrition because photosynthesis enhanced by the growth and development of leaf area [21]. In agreement with this result, Tairo and Ndakidemi [22] also reported that phosphorus application have significantly increased the leaf area and leaf area index on soybean.

Concerning plant spacing, LAI was significantly decreased from 3.51 to 2.46 as inter-row spacing increased from 30 to 50 cm. Similarly, it was decreased from 4.19-2.09 due to increasing intra-row spacing from 5 cm to 15 cm (Table 2). Moreover, the highest 3.5 and 4.19 LAI was obtained at the narrowest inter-and intra-row spacing of 30 cm and 5 cm, respectively. In conformity with this result, Caliskan , *et al.* [23] and Solomon [24] all worked on haricot bean reported that leaf area index was increased as both inter and intra-row spacing decreased

### 3.2.2. Number of Primary Tillers per Plant

Analysis of variance revealed that highly significant ($P<0.01$) effect of main effects of phosphorus rates, inter-and intra-row spacing on number of primary tillers per plant (Table 2). The significantly highest and lowest number of primary tillers per plant was recorded at the highest rate of P (92 kg $P_2O_5$ ha$^{-1}$) and the lowest rate of P (0 kg $P_2O_5$ ha$^{-1}$), respectively. Number of primary tillers plant$^{-1}$ was significantly increased due to application of 46 and 92 kg $P_2O_5$ ha$^{-1}$rates P by 13.7 and 35.3% over the control. The increment in number of primary tillers per plant in response to the increased phosphorus application rate indicates higher vegetative growth of the plants under higher P availability. In line with this result, Shubhashree [25] reported that significantly higher number of primary tillers per plant of common bean with 75 $P_2O_5$ kg ha$^{-1}$ rate of P over the control. Number of primary tillers per plant was increased with increasing of inter and intra-rows spacing wherein the highest 2.99 and 3.33 number of primary tillers were recorded at the widest inter-and intra-rows of 50 cm and 15 cm, respectively. Meanwhile, the widest plant spacing of 50 cm inter and 15 cm intra-rows gave significantly higher tiller number and the narrowest spacing of 30 cm inter and 5 cm intra-rows gave lower number of primary tillers (Table 4). This is due to the fact that, as space among plants increased ample resources become available for each plant that enhances the lateral vegetative growth of the crop. In agreement with this result, Mehmet [26] who reported that increased number of primary tillers due to wider plant spacing for soybean. Similarly, Khalil, *et al.* [27] and Yucel [28] also reported there was a trend that number of primary tillers was increased as the space among plants increased compared to plants at narrow spacing.

### 3.2.3. Plant Height

Analysis of variance showed that highly significant ($P<0.01$) variation due to main effects of P, inter and intra-row spacing and statistical significant ($P \leq 0.05$) difference due to interaction effect of inter and intra-row spacing on plant height. Significantly highest plant height (105.63 cm) was obtained at the highest rate of P (92 kg $P_2O_5$ ha$^{-1}$) while the lowest plant height (89.43 cm) was due to no phosphorus application (Table 2). The increase in plant height in response to the increased P application rate indicates higher vegetative growth of the plants under higher P availability. In agreement with this result, Getachew and Rezene [29] reported that plant height of faba bean was significantly influenced by P application compared to control plots in holeta area, central Ethiopia.

**Table-2.** Main effects of phosphorus rates on leaf area index (LAI), number of primary tillers per plant, plant height and main effects of inter and intra rows spacing on LAI and number of primary tillers per plant of faba bean

| **Treatments** | **LAI** | **Number of tillers plant$^{-1}$** | **plant height (cm)** |
|---|---|---|---|
| Phosphorus rates (kg $P_2O_5$ $ha^{-1}$) | | | $89.43^{a}$ |
| 0 | $2.81^{a}$ | $2.41^{a}$ | $96.93^{b}$ |
| 46 | $3.01^{b}$ | $2.74^{b}$ | $105.63^{c}$ |
| 92 | $3.13^{b}$ | $3.26^{c}$ | 2.271 |
| LSD (0.05) = | 0.194 | 0.091 | |
| Inter –row spacing (cm) | | | |
| 30 | $3.51^{c}$ | $2.54^{a}$ | |
| 40 | $12.97^{c}$ | $2.86^{b}$ | |
| 50 | $2.46^{a}$ | $2.99^{c}$ | |
| LSD (0.05) = | 0.167 | 0.065 | |
| Intra-row spacing (cm) | | | |
| 5 | $4.19^{c}$ | $1.52^{a}$ | |
| 10 | $2.65^{b}$ | $3.03^{b}$ | |
| 15 | $2.09^{a}$ | $3.33^{c}$ | |
| LSD (0.05) = | 0.185 | 0.078 | |
| CV (%) = | 11.9 | 6 | |
| Mean values within column followed the same letter (s) are not significantly different, LSD = Least Significant Difference at 5% level; CV= Coefficient of Variation | | | |

The interaction effect of 30 cm inter and 5 cm intra- row spacing resulted in significantly tallest plants (135.2 cm) while statistically shortest plants (79 cm) were due to50 cm by 15 cm spacing combination (Table 3). Taj, *et al.* [30], who worked experiment on mungbean reported that more competition for light in narrow spacing that resulted in taller plants while at wider spacing light distribution was normal. Likewise, Shamsi and Kobraee [31] who worked experiment on spacing reported that decreased spacing among plants (increase density of plants) lead to significant increases in plant height of soybean.

**Table-3.** Interaction effects of inter and intra-row spacing on plant height (cm) of faba bean

| **Inter-row** | **Intra-row spacing (cm)** | | |
|---|---|---|---|
| spacing (cm) | 5 | 10 | 15 |
| 30 | $135.2^{a}$ | $100.74^{d}$ | $101.28^{d}$ |
| 40 | $117.08^{b}$ | $88.3^{e}$ | $84.84^{ef}$ |
| 50 | $111.26^{c}$ | $83.27^{f}$ | $79^{g}$ |
| LSD (0.05) = | 3.934 | | |
| CV (%) = | 4.2 | | |
| Mean values within column followed the same letter (s) are not significantly different, LSD = Least Significant Difference at 5% level; CV= Coefficient of Variation | | | |

## 3.3. Yield Components and Yield

### 3.3.1. Number of Pods per Plant

The analysis of variance indicated that the interaction of inter and intra rows spacing had highly significantly ($P<0.01$) effect on number of pods per plant whereas the other factors were not significant. The interaction of 50 cm inter-row by 15 cm intra-row spacing gave the highest (19.68) number of pods per plant and the lowest (6.42) was due to 30 cm inter by 5 cm intra-row spacing combination (Table 4). The increment in number of pods per plant at the widest inters and intra-rows spacing interactions (50 cm x 15 cm) might be due to increase in net assimilation rate and reduction of competition in wider spacing. In addition, at wider spacing the growth factors (nutrient, moisture and light) for individual plants might be easily accessible that retained more flowers and supported the development of pods. In line with this result, Melak [32] reported that significantly highest number of pods plant$^{-1}$ (34.7) was recorded at 50 cm x 15 cm spacing combination as compared to 20 cm x 5 cm spacing (16.7) on chickpea.

**Table-4.** Interaction effects of inter and intra-row spacing on number of pods per plant of faba bean

| **Intra-row spacing (cm)** | | | |
|---|---|---|---|
| Inter-row spacing | 5 | 10 | 15 |
| (cm) | | | |
| 30 | $6.42^{a}$ | $10.01^{d}$ | $16.82^{e}$ |
| 40 | $8.17^{b}$ | $16.54^{e}$ | $17.36^{e}$ |
| 50 | $11.61^{c}$ | $16.67^{e}$ | $19.68^{f}$ |
| LSD (0.05) =1.437 CV (%) = | 11.3 | | |
| Mean values within column followed the same letter (s) are not significantly different, LSD = Least Significant Difference at 5% level; CV= Coefficient of Variation | | | |

### 3.3.2. Number of Seeds per Pod

All main effects and interaction of inter- and intra-row spacing revealed that highly significant (P<0.01) effect on the number of seeds per pod but the other interactions did not affect the trait. Significantly highest number of seeds per pod (3.57) was obtained at the highest rate of phosphorus (92 kg $P_2O_5$ $ha^{-1}$) application while the lowest (2.99) was recorded from the control treatment (Table 9). The number of seeds per pod increased significantly as the rate of P increase from 0 to 92 kg $P_2O_5$ $ha^{-1}$. The highest seed number seeds per pod at the highest rate of P may be due to positive role of P more in photosynthetic materials production and allocation and its transfer to reproduction organs of the crop. The result is agreed with Meseret and Amin [33] who reported that the significantly highest number of seeds per pod (5.85) was obtained at the highest rate of P (40 kg $P_2O_5$ $ha^{-1}$) and the lowest (3.14) was recorded on the untreated plot.

With regard to the interaction effects of inter and intra-row spacing, the highest and lowest number of seeds per pod was recorded for plants $ha^{-1}$ grown at 50 cm x 15 cm and 30 cm x 5 cm spacing combinations, respectively (Table 5). The interaction could be explained due to 15 cm intra-row as compared to 5 and 10 cm in which at 15 cm it was significantly increased as inter-row spacing increased from 40 to 50 cm, but at 5 and 10 cm there was not significant increase between 40 and 50 cm. The result agrees with that of Mahmoud [34] who reported that the number of seeds per pod of faba bean decreased with close planting. Similarly, Bakry, *et al.* [35] on their work on effect of row spacing on yield and its components of some faba bean varieties under newly reclaimed sand soil conditions reported that the highest number of seeds per pod was obtained from the wider spaced plants compared to close spaced plants.

**Table-5.** Interaction effects of inter and intra-row spacing on seeds per pod of faba bean Intra-row spacing (cm)

| **Intra-row spacing (cm)** | | | |
|---|---|---|---|
| Inter-row spacing | 5 | 10 | 15 |
| (cm) | | | |
| 30 | 1.92$^{a}$ | 3.06$^{c}$ | 3.71$^{d}$ |
| 40 | 2.84$^{b}$ | 3.49$^{c}$ | 3.76$^{d}$ |
| 50 | 2.87$^{b}$ | 3.51$^{c}$ | 3.97$^{e}$ |
| LSD (0.05) = 0.147 | | | |
| CV (%) = 4.9 | | | |
| Where means in column followed by the same letter (s) are not significantly different at 5% level of significance, LSD (0.05) = Least Significant Difference and CV= Coefficient of Variation | | | |

### 3.3.3. Hundred Seed Weight

Main effects of phosphorus, inter and intra-row spacing showed highly significant (P<0.01) effect on hundred seed weight while their interactions did not show significant effect on the yield parameter. The highest and lowest hundred seed weight was recorded with application of 92 kg $P_2O_5$ $ha^{-1}$ and 0 kg $P_2O_5$ $ha^{-1}$ rates of P, respectively (Table 6). The increment with application of P fertilizer might be due to the adequate supply of P could be attributed to an increase the weight of seeds. This in turn increased photosynthetic area and more dry matter portioning from source to sink and economic part, which demonstrates a strong correlation with size of seed. The result is in line with that of Girma [36] who reported that hundred seed weight and dry matter accumulation were increased with application of phosphorus fertilizer compared to control plots. Similarly, Yamane and Skjelvåg [37] who conducted experiment on field pea indicated that with increasing P application in the soil was increased hundred seed weight.

The highest hundred seed weights of 54.59 g and 56.1 g were recorded with the wider inter- and intra- rows spacing of 50 cm and 15 cm, respectively while the lowest was due to 30 cm inter and 5cm intra-row spacing (Table 6). Hundred seed weight was significantly increased as inter and intra-row spacing increased. This increment might be because of assimilates division between higher numbers of seed used in connection with the decreased inter plant competition that lead to increased plant capacity, for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components. In conformity with this result, Tesfaye [38] reported that seed weight of faba bean was significantly increased with increasing intra-rows from 10 to 25 cm and the highest value (49 g) obtained at 25 cm plant spacing compared to the narrowest spacing.

**Table-6.** Main effects of phosphorus rates, inter and intra-row spacing on 100-seed weight of faba bean

| Phosphorus rates (kg $P_2O_5$ ha$^{-1}$) | 100-seed weight (g) |
|---|---|
| 0 | 46.33$^{a}$ |
| 46 | 51.48$^{b}$ |
| 92 | 57.44$^{c}$ |
| LSD (0.05) = 1.348 | |
| Inter-row spacing (cm) | |
| 30 | 43.96$^{a}$ |
| 40 | 48.7$^{b}$ |
| 50 | 54.59$^{c}$ |
| LSD (0.05) = 1.465 | |
| Intra-row spacing (cm) | |
| 5 | 41.85$^{a}$ |
| 10 | 50.3$^{b}$ |
| 15 | 56.1$^{c}$ |
| LSD (0.05) = 1.354 | |
| CV (%) = 5.1 | |
| LSD: Least Significance Difference, CV: Coefficient of Variation | |

### 3.3.4. Above Ground Dry Biomass Yield (DBY)

The analysis of variance revealed that all main effects and interaction effects of inter and intra row spacing were highly and significantly ($P<0.01$) affected above ground dry biomass yield. However, the other interactions did not affect the attribute. The result showed that there was significantly increase in biomass yield when P application was increased from the lowest to the highest rate (Table 9). The increase in above ground dry biomass at the highest rate of phosphorus might be attributed to the enhanced availability of P for vegetative growth of the crops. There is similar on findings from Tesfaye [38] reported that the highest (8135 kg ha$^{-1}$) and the lowest (4399 kg ha$^{-1}$) dry biomass yield recorded from 30 kg $P_2O_5$ ha$^{-1}$ and 0 kg $P_2O_5$ha$^{-1}$rates of P, respectively on common bean.

Concerning the interaction effect of inter and intra-row spacing, significantly highest above ground dry biomass yield (8738kg ha$^{-1}$) was recorded at 30 cm inter by 5 cm intra-row spacing combination which was statistically similar with the dry biomass obtained due to 40 cm by 5 cm inter and intra-row spacing combination, and the lowest (3812 kg ha$^{-1}$) was obtained with 50 cm x 15 cm inter and intra-row spacing interaction (Table 7). In line with this result, Solomon [39] reported that above ground dry biomass yield per ha was significantly increased with decreasing plant spacing on soybean due to increased dry matter accumulation in densely populated crops. Similarly, Derogar, *et al.* [40] reported that increasing plant density resulted in increasing of biological yield of faba bean.

**Table-7.** Interaction effects of inter- row and intra-row spacing on dry biomass yield (kg ha$^{-1}$)

| Intra-row spacing (cm) | | | |
|---|---|---|---|
| Inter-row spacing | 5 | 10 | 15 |
| (cm) | | | |
| 30 | 8738$^{g}$ | 7678$^{e}$ | 7187$^{c}$ |
| 40 | 8656$^{g}$ | 7594$^{e}$ | 5549$^{b}$ |
| 50 | 8184$^{f}$ | 6579$^{d}$ | 3812$^{a}$ |
| LSD (0.05) = 276.4 CV (%) = | 13.8 | | |
| Means in columns and rows followed by the same letter (s) are not significantly different at 5% level of significant, LSD (0.05) = Least Significant Difference at 5% level and CV= Coefficient of Variation | | | |

### 3.3.5. Grain Yield (Kg Ha$^{-1}$)

The analysis of variance indicated that there was highly significant ($P<0.01$) effect of all main effects and interaction effects of inter and intra-row spacing while the other factors were not significantly affect grain yield. Phosphorus application rate was significantly increased grain yield. The highest rate of P fertilizer (92 kg $P_2O_5$ ha$^{-1}$) gave the highest grain yield (2633 kg ha$^{-1}$) while the lowest (1508 kg ha$^{-1}$) was obtained from the control plot (Table 9).The highest grain yield with the highest P rate might be attributed to the fact that applying phosphorus fertilizer increases crop growth and yield on soils which are naturally low in P and in soils that have been depleted [41].The current result is similar with those of Tekle, *et al.* [42] who, reported that significantly highest grain yield (3814.8 kg ha$^{-1}$) was recorded at the highest rate of P (46 kg$P_2O_5$ ha$^{-1}$) compared to 23 kg $P_2O_5$ ha$^{-1}$ rate of P (3585.6 kg ha$^{-1}$) and control treatments due to enhanced grain yield by translocation of photo assimilates from vegetative biomass to grains.

With regard to the interaction effect of inter and intra-row spacing, significantly highest grain yield (2495 kg ha$^{-1}$) was obtained with 30 cm x 15 cm spacing combination and the lowest (1329kg ha$^{-1}$) was recorded due to 30 cm by 5 cm spacing interaction which was statistically similar with grain yield obtained at 50 cm x 15 cm spacing combination (Table 8). In agreement with the result [32] who, reported that the highest (1219 kg ha$^{-1}$) and the lowest (733 kg ha$^{-1}$) grain yields were recorded at 30 cm x 10 cm and 20 cm x 5 cm spacing combination, respectively of common bean. Similarly, Biabani [43] reported that highest grain yield of chickpea was obtained when plants grown at 45 cm x 7.5 cm spacing while plants grown at 35 cm x 5 cm spacing combination gave the lowest yield.

**Table-8.** Interaction effect of inter and intra-row spacing on grain yield (kg $ha^{-1}$) of faba bean

| **Intra-row spacing (cm)** | | | |
|---|---|---|---|
| Inter- row | 5 | 10 | 15 |
| spacing (cm) | | | |
| 30 | 1329$^{a}$ | 2169$^{c}$ | 2495$^{e}$ |
| 40 | 1545$^{b}$ | 2378$^{d}$ | 1966$^{f}$ |
| 50 | 1606$^{b}$ | 2154$^{c}$ | 1365$^{a}$ |
| LSD (0.05) = 99.3 | | | |
| CV (%) = 7.2 | | | |
| Means in columns and rows followed by the same letter (s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation | | | |

### 3.3.6. Harvest Index (%)

The analysis of variance showed that all main effects and interactions of inter-and intra-row spacing had highly significant (P<0.01) effect while the other interactions had no significant effect on harvest index (HI). Significantly highest harvest index was obtained with application of 92 kg $P_2O_5$ $ha^{-1}$ and the lowest was recorded at the control treatment (Table 9). This increment in harvest index with application of P fertilizer might be due to the fact that adequate supply of phosphorus could be attributed to an increase grain yield due to translocation of highest amounts of photo-assimilates to grains. Amanuel, *et al.* [44] also confirmed that harvest index of faba bean was increased by application of 20 kg $P_2O_5$ $ha^{-1}$ rate of P due to enhanced grain yield production compared to control treatment. Similarly, Rakesh, *et al.* [45] and Murat, *et al.* [46] also reported significant increase in harvest index of mungbean and field pea due to phosphorus application, respectively.

**Table-9.** Main effect of phosphorus rates on number of seeds per pod (NSPP), above ground dry biomass yield (DBY), grain yield (GY) and harvest index (HI) of faba bean

| **Phosphorus rates (kg $P_2O_5ha^{-1}$)** | **NSPP** | **DBY (kg)** | **GY (kg)** | **HI (%)** |
|---|---|---|---|---|
| 0 | 2.96$^{a}$ | 6952$^{a}$ | 1508$^{a}$ | 21.59$^{a}$ |
| 46 | 3.15$^{b}$ | 7544$^{b}$ | 2199$^{b}$ | 29.39$^{b}$ |
| 92 | 3.57$^{c}$ | 8108$^{c}$ | 2633$^{c}$ | 32.47$^{c}$ |
| LSD (0.05) = | 0.085 | 159.6 | 57.3 | 1.049 |
| CV (%) = | 4.9 | 13.8 | 7.2 | 15.3 |
| LSD (0.05) = Least Significant Difference at 5% level | | | | |

Regarding the interaction effects of inter and intra-row spacing, harvest index was increased with increasing inter and intra-row spacing. Significantly highest harvest index(HI) value (35.79%)was achieved for the interaction of 50 cm by 15 cm inter-and intra-row spacing which was statistically at par with HI obtained with 30 cm x 15 cm and 40 cm x 15 cm spacing combinations and the lowest (15.29%)was due to 30 cm x 5 cm spacing combination (Table 10). At the narrower plant spacing, the adverse effect on grain yield was noticed which might be due to intense plant competition for nutrients, moisture and light resulting in increased flower abortion, subsequently reduced harvest index. Mahmoud [34] reported that harvest index was significantly affected by inter-and intra-row spacing and significantly highest HI value (34.5%) was recorded from the wider spacing combination (50 cm x 25 cm) as compared to narrower (40 cm by 15 cm) inter and intra-rows (21.6%). Similarly, Yucel [28] reported that increased harvest index of local bean as plant populations decreased compared to densely populated plants.

**Table-10.** Interaction effect of inter and intra-row spacing on harvest index (%) of faba bean

| **Intra-row spacing (cm)** | | | |
|---|---|---|---|
| Inter-row | 5 | 10 | 15 |
| spacing (cm) | | | |
| 30 | 15.29$^{a}$ | 28.39$^{d}$ | 34.67$^{f}$ |
| 40 | 17.88$^{b}$ | 31.39$^{e}$ | 35.48$^{f}$ |
| 50 | 19.79$^{c}$ | 32.61$^{e}$ | 35.79$^{f}$ |
| LSD (%) = 1.816 | | | |
| CV (%) = 15.3 | | | |
| Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant, LSD (0.05) = Least Significant Difference at 5% level and CV= Coefficient of Variation | | | |

# 4. Summary Conclusion

The results from the study showed that phosphorus rates had significance effect on days to flowering, days to physiological maturity, leaf area index, plant height, number of primary tillers per plant, number of seeds per pod, hundred seed weight, above ground dry biomass, grain yield and harvest index. Thus, the highest rate of P (92 kg $P_2O_5$ ha$^{-1}$) gave lowest days to flowering (54.3 days) and days to maturity (133.9 days) whereas the prolonged period for days to flowering (57.89 days) and maturity (136.3 days) was achieved at the control treatment. Significantly highest leaf area index ( 3.13), plant height (105.63 cm), number of primary tillers (3.26), number of seeds per pod (3.57), hundred seed weight (57.44 g), above ground dry biomass (8108 kg ha$^{-1}$), grain yield (2633 kg ha$^{-1}$) and harvest index (32.47%) were recorded from the highest rate of P (92 kg $P_2O_5$ ha$^{-1}$). In general, faba bean showed remarkable response to the application of phosphorus.

The main effects of inter and intra-row spacing were highly significant on days to 50% flowering, days to 90% maturity leaf area index, number of primary tiller per plant and hundred seed weight. Accordingly, row spacing of 50 cm was earlier (55.96 days) while row spacing of 30 cm took the longest number of days to flower (57.48 days). And regarding the intra-rows, 5 cm intra-row spacing took significantly longer days (57.26 days) as compared to the others and 15 cm intra-row spacing took the least days to flower (54.59 days). Days to 90% physiological maturity was increased with decreasing inter-row spacing from 132.4 days at 50 cm to 136.1 days at 30 cm. Similarly, days to maturity was increased from 133.1 to 135.5 days as intra-row spacing decreased from 15 cm to 5 cm, respectively.

The interaction effect of inter and intra row spacing was statistically significant ($P \leq 0.05$) on plant height. Significantly tallest plants in height (135.2 cm) were recorded due to 30 cm x 5 cm spacing combination whereas the shortest (79 cm) plants were obtained on 50 cm x 15 cm spacing interaction. Similarly, the interaction effects of inter and intra-row spacing were highly significant on number of pods per plant, number of seeds per pod, above ground biomass, grain yield and harvest index. Accordingly, the interactions of 50 cm by 15 cm inter and intra-rows gave highest (19.68) number of pods per plant and number of seeds per pod (3.97). Harvest index was increased as inter and intra-row spacing increased and significantly highest harvest index ( 35.79%) was recorded due to 50 cm and 15 cm spacing combination which was statistically at par with harvest index obtained at 30 cm x 15 cm and 40 cm x 15 cm spacing combinations.

The interactions of 30 cm inter and 15 cm intra-row spacing gave significantly highest grain yield (2495 kg ha$^{-1}$) while the lowest (1329 kg ha$^{-1}$) was due to 30 cm x 5 cm spacing combination which was statistically similar with grain yield obtained at 50 cm x 15 cm spacing combination. Above ground dry biomass yield was increased as inter and intra-row spacing decreased and significantly highest dry biomass yield (8738 kg ha$^{-1}$) was recorded with the interaction of 30 cm inter and 5 cm intra-rows whereas the lowest (3812 kg ha$^{-1}$) was recorded due to 50 cm by 15 cm spacing combination. From this study, it can be concluded that in such phosphorus limited soils, application of 92 kg $P_2O_5$ ha$^{-1}$ with 30 cm inter and 15 cm intra-row spacing had resulted in higher grain yield and economic return. However, this study was done for one seasons at one location, the experiment has to be repeated over years to determine the optimum phosphorus rate and plant spacing. However, to make reliable and acceptable conclusion it is better to repeat this experiment across different locations and over seasons and different types of soils.

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