Influence of Phosphorus Fertilizer Rates on Yield and Yield Components of Faba Bean (*Vicia faba* L.) Varieties in Lemu Bilbilo District of Arsi Zone, Southeastern Ethiopia

ABSTRACT

Faba bean production is a common practice in Lemu Bilbilo areas. However, faba bean productivity is affected and limited by poor soil fertility and lack of alternative technologies such as application of optimum phosphorus fertilizer for different faba bean varieties. In view of this, a field experiment was conducted on farmer's field during the 2017 main cropping season at Lemu Bilbilo with the objectives to determine the response of faba bean varieties to different rates of P fertilizer and its influence on yield and yield components of faba bean varieties. The treatments include three faba bean varieties (Tumsa, Gebelcho and Dosha) and five phosphorus levels (0, 10, 20, 30 and 40 kg P ha^{-1}) from Triple Super Phosphate. The experiment was laid out in a randomized complete blocked design with 3 x 5 factorial arrangements with three replications. Significantly (P= .05) higher plant height was recorded from Tumsa variety. Total productive tillers per plant, thousand seed weights, and harvest index and biomass yield of faba bean were significantly affected by main effect of varieties. Higher total productive tillers per plant (1.53) were obtained from application of 30 kg P ha^{-1}. Higher plant height (153 cm), biomass yield (14158 kg ha^{-1}) and grain yield (6323 kg ha^{-1}) were obtained from application of 40 kg P ha^{-1}. Application of 10, 20 and 30 kg P ha^{-1} gave marginal rate of return of 1404694 and 502% for faba bean production, which are well above the minimum acceptable rate of return. Therefore, application of 20 kg ha^{-1} of P with Tumsa, Gebelcho and Dosha faba bean varieties were proved to be productive and superior both in seed yield as well as economic advantage and recommended for faba bean production in Lemu Bilbilo area. Further study should be conducted in the future both over locations and years in order to give full recommendation for practical application.

***Key words**: Faba bean, phosphorus rates, available phosphorus, soil pH*

1. INTRODUCTION

Faba bean *(Vicia faba* L.) is among the major grain food legumes cultivated in different parts of Ethiopia including Arsi zone [1]. Faba bean is one of the most popular legumes which is tightly coupled with every life of Ethiopians and grown during the main season on both red and black soils primarily in Oromia, Amhara, Tigray, and SNNP regional states [2]. The crop is also producing in large area next to cereals in Arsi zone of Oromia. It is grown from 1300 to 3800 m altitude, but mostly at 2000 to 2500 m [3]. The crop is well adapted to diverse soil types of Ethiopia where legumes are prominently used as traditional soil fertility maintenance crops in mixed cropping systems. Of the major cool season grain legumes, faba bean has the highest average reliance on N_2 fixation for growth [4]. The use of faba bean crop rotation had a significant effect by reducing the amount of chemical nitrogen applied to soil for crop production [5]. The straw of faba bean is also used as animal feed and soil fertility restorer [6]. The average national productivity of faba bean is 2.1 t ha^{-1} but, is low as compared to the world top producers [1]. As [7] reported that the productivity of faba bean in Ethiopia is quite low as compared to in UK, which is about 3 t ha^{-1}. Faba bean production in Ethiopia is also limited and fails to face the increasing local consumption of seeds due to gradual decreases in its average yield. The production and productivity of faba bean is constrained by several biotic and abiotic stresses of which lack of improved varieties, shortage of certified seeds, diseases such as rust, powdery mildew and root rot, insect pests such as aphids and low soil fertility, acidity of the soil in high rainfall areas and low existence of effective indigenous rhizobia are the major ones and becoming a major challenge to food security. So, increasing crop production is the major target of the national agriculture policy and can be achieved by growing high yielding and stable cultivars under favorable environmental conditions [8].

According to [9] reported that improved agronomic practices increased the grain yields by 88% over the yields of conventional farmers' practices. Besides, different varieties have different responses to inputs of production. Substantial yield differences between researcher and farmers managed trials are known to occur due to crop management applied and input use and other environmental factors. However, improper use of inorganic fertilizer is one of the main causes of environmental degradation in Africa [10]. Low and unbalanced application rates per unit area of land mainly focusing on Urea and DAP fertilizers with low efficiency of the fertilizers [3] and limited use of improved seeds [11] have still remained major constraints for small farmers to get the best out of the input.

The lack or low rates of essential elements like P in the soil is one of the factors negatively affect growth and yields of faba bean. Phosphate can readily be rendered unavailable to plant roots as it is the most immobile of the major plant nutrients. In spite of the considerable addition of phosphorus to soil, the amount available for plant is usually low. Phosphorus fertilization has positive effect on faba bean yield and yield components [12]. The high variability of productivity among smallholder farmers can be attributed to soil characteristics, quality of field management, input use, geophysical characteristics such as altitude and weather conditions, demographic and market situations [13]. The use of mineral fertilizers to increase faba bean productivity by Ethiopian farmers is also low and this makes the farmers to produce faba bean below its potential.

Faba bean is also a very important crop in the Arsi zone grown to break the monoculture wheat-based farming system that always suffers from attacks by new races of rust with significant yield reductions. In Ethiopia research work regarding use of P and its role in legume growth, nodulation, N_2 fixation and grain yield and yield components is very limited. Inclusion of this crop in the crop rotation system with the application of optimum phosphorus fertilizer which is a limiting factor for the production of faba bean is crucial in the highlands like study area. Indeed, testing of the alternative technology for different varieties is very essential to assess its feasibility and ascertain the response of improved varieties to inputs of production in the region. Therefore, the objective was to determine the response of faba bean varieties to different rates of phosphorus fertilizer rates on yield and yield components of faba bean in Lemu Bilbilo district.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Field experiment was conducted in Lemu Bilbilo district, Arsi Zone of Oromia Regional National State, Southeastern Ethiopia in 2017 main cropping season. Lemu Bilbilo lies between 7.55 ^oN and 8.26 ^oN latitude and 39.23^{o}E and 39.26 ^{o}E longitude at an altitude of 2780 meters above sea level with the agro-ecology of sub-humid tropics and high rainfall. The average mean minimum and maximum temperature are 7.9 and 18.6 ^oC respectively. It receives mean annual rainfall of 1020 mm with quasi bi-modal distribution and maximum (202 mm) occurs in August (KARC, unpublished). The soils of the study area are classified Nitisols with the pH of 5.0 [14].

2.2. Treatments and Experimental Design

Factorial combinations of three faba bean varieties (Tumsa, Gebelcho and Dosha) and five phosphorus levels (0, 10, 20, 30 and 40 kg P ha^{-1}) from TSP were used for the experiment. The experiment was laid out in a randomized complete blocked design with 3 x 5 factorial arrangements with three replications. The seed rate of faba bean was 200 kg ha^{-1} for each variety. The gross and net plot size of each plot were 2.6 m x 4 m (10.4 m^2) and 2.6 x 2.4 m (6.24 m^2). Triple Super Phosphate and urea were used as source of phosphorus and nitrogen respectively. Faba bean seeds were sown in row with 40 cm inter rows and 10 cm intra row spacing. Applications of different rates of phosphorus fertilizer as Triple superphosphate were done in the rows of faba bean seed once at planting. Nitrogen (18 kg N ha^{-1}) fertilizer was applied as urea uniformly at sowing in rows of faba bean and mixed to soil and improved agronomic management practices (weeding, hoeing, disease management etc.) was applied for faba bean during the growing period.

2.3. Soil Sampling, Preparation and Analysis

Soil samples from the experimental site were taken before planting of faba bean. One representative composite soil sample was collected from ploughed and leveled field from three places diagonally across the field (in grid form or by zigzag method) with auger from 0 to 20 cm depth of top soil. The composited soil sample taken was air-dried at room temperature, thoroughly mixed and ground to pass through a 2 mm sieve and subjected to analysis for selected soil physico-chemical properties before planting. The selected physical and chemical properties of composited soil sample subjected to analysis were soil texture, exchangeable acidity, soil pH, organic carbon (OC), total N, available P, exchangeable bases (Na, K, Ca, and Mg) and CEC following standard laboratory procedures for each parameter.

Undisturbed surface soil sample was collected using core sampler from the experimental field to determine bulk density of the soil before planting. The soil core was removed from undisturbed soil by driving the cylinder into the soil with block of wood and hammer. The soil core was examined and the ends were trimmed carefully. Then the soil and the cylinder were weighed; the weight of the soil sample alone was calculated by subtracting the weight of the cylinder. Portion of the soil was taken for determination of soil moisture and the oven-dry weight of the sample was calculated. Lastly, the bulk density (g cm^{-3}) of the soil was calculated from weight of oven dry soil core (g) and volume of soil core (cm^3) [15].

Soil texture was determined using the Bouyoucos hydrometer method [16] and organic matter content was determined by the oxidation of organic carbon with acid potassium di-chromate ($K_2Cr_2O_7$) medium using the Walkley and Black method as described by [17]. The pH of the soil was measured or determined by using potentiometric method at 1:2.5 (weight/ volume) soil to water dilution ratio using a glass electrode attached to digital pH meter [18]. Total nitrogen was determined by using Kjeldahl method as described by [19] and also available phosphorus was determined by using the Bray II method [20]. Cation exchange capacity (CEC**)** was measured after saturating the soil with 1N ammonium acetate (NH_4OAC) and displacing it with 1N NaOAC and was determined from ammonium acetate saturated samples that was subsequently replaced by Na from a percolated sodium chloride solution [21]. The excess salt was removed by washing with alcohol and the ammonium that was replaced by sodium was measured by using the Kjeldahl method as described by [22]. Exchangeable bases were extracted with 1M ammonium acetate at pH 7.0. Exchangeable Ca and Mg were measured from the extract with atomic absorption spectrophotometry while exchangeable K and Na were determined from the same extract with flame photometry. Total exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by [23].

2.4. Data Collection

Different crop parameters were collected at various growth stage of faba bean.

Plant height: was measured at physiological maturity from five randomly selected plants per plot by measuring the height from the ground level to the apex of the plant and averaged it.

Number of productive tillers per plant: was determined at maturity by counting all tillers producing/setting pods from five randomly selected plants from each plot at physiological maturity of faba bean and averaged them as per plant.

Number of pods per plant: were determined by counting the number of pods per plant from five randomly selected plants from each plot at harvest and considered the average per plant.

Number of seeds per pod: were recorded from five randomly selected plant pods from each net plot area at harvest and averaged as per pod.

Dry biomass: was obtained from plants harvested at maturity from net plot area (six central rows) of each plot and sun dried it for 48 hrs. Then the data was converted to kg per hectare.

Thousand seed weights: of the plant was determined by weighing 1000 randomly selected seeds from the harvest of each plot after the seeds adjusted to 10% moisture level.

Grain yield: was harvested from six central rows that were considered for dry biomass yield were threshed to determine grain yield after adjusting the moisture content of the seeds 10%. Finally, yield per plot was converted to per hectare and the average yield was reported in kg ha^{-1}.

Harvest index: was computed as a ratio of seed yield (kg ha^{-1}) to dry biomass yield (kg ha^{-1}) *100.

3. RESULTS AND DISCUSSION

3.1. Some Soil Physico-chemical Properties of the Experimental Site

The soil texture distribution of the experimental site was clay loam (Table 1). The soil reaction of the experimental sites is strongly acidic [24] rating. This indicates that the soil experimental site requires soil amendment with lime to make it suitable for optimum growth and yield of most crops. The available P level was (0.7 mg kg^{-1} of soil) (Table 1) which is found in very low range as [25]. This indicates that the available P of the study area is very low which point us P fertilizer application is crucial for the study area in order to maximize faba bean production. The low available phosphorus could be due to P fixation in such acidic soils and removal of basic cations such as Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} from the top soil because of high rain fall of the area. The total nitrogen percentage of the experimental field was 0.18% (Table 1) and found in low range [24]. The cation exchange capacity of the experimental soil was 14.1cmol (+) kg^{-1} which is found in low range [26]. The total carbon content in the soils was 1.33%. The concentrations of exchangeable Ca (7.7 cmolc kg^{-1}), Mg (1.68 cmolc kg^{-1}), and Na (0.47 cmolc kg^{-1}) were medium to low except that of K (1.23 cmolc kg^{-1}) which was high. The bulk density of the soils of the experimental site is 1.39 g cm^{-3}.

3.2. Plant Height

The mean plant height of faba bean is indicated in Table 2. The main effect of faba bean varieties had a highly significant ($P < 0.001$) effect on plant height of faba bean. Significantly higher mean plant height of (157 cm) was recorded from Tumsa variety whereas, variety Gebelcho resulted shortest (138 cm) stature plants followed by Dosha variety (141 cm). Gebelcho variety is considered as dwarf variety as compared to the other two varieties. Likewise, [29] reported that a variety called Gebelcho was the shortest variety. According to Talal and Munqez [30] reported that plant height was significantly affected by faba bean accessions. Application of different rates of phosphorus had highly significant ($P<0.05$) effect on plant height of faba bean (Table 2). Application of 40 kg P ha^{-1} resulted in long stature plants (153 cm) followed by 30 kg P ha^{-1} (151 cm). The short stature plants (145 cm) were observed in control plots followed by application of P at 10 kg P ha^{-1}. Phosphorus application at the rate of 40 kg P ha^{-1} might be the optimum rate to trigger an increase in plant height with per unit increase in phosphorus rate as deduced from the control plots. As P levels increase from 0 kg P ha^{-1} to 40 kg P ha^{-1} the plant height was increased by 14%. It was reported that, promotion effect of higher P level on plant height was probably due to better development of root system and nutrient absorption [31]. Likewise, [32] reported an increase in plant height of faba bean both at 50% flowering and maturity stage in response to increased P application.

3.3. Total Productive Tillers per plant

The main effect of faba bean varieties had highly significant ($P< 0.001$) effect on total number of effective tillers plant^{-1} (Table 2). Significantly higher number of effective tillers plant^{-1} (1.53) was recorded from Gebelco variety, whereas, the lowest number of effective tillers plant^{-1} was obtained from Tumsa variety which is as par statistically Dosha variety (Table 2). This might be due to variation in genotype of the faba bean varieties. In contrary, [33] found that faba bean varieties had no significant effect on number of tillers plant^{-1}. The effect of different levels of P on number of effective tiller plant^{-1} showed significant ($P<0.05$) difference for faba bean (Table 2). The application of 30 kg P ha^{-1} resulted in higher number of effective tillers plant^{-1} (1.53), which was at par with all other P rates application except the control (1.18). This indicated that P at the rate of 30 kg ha^{-1} might be the optimum rate for improvement of number of effective tiller plant^{-1} that ultimately had directly affected grain yield of faba bean. Further increase in P rate above 30 kg ha^{-1} did not have a linear effect on the number of effective tillers plant^{-1} of faba bean which is obvious from the plots with P applied at the rate of 40 kg ha^{-1} that had less number of effective tiller plant^{-1} even though both treatments were statistically at par. As P is responsible for good root growth which directly affects the overall plant performance, the regimes of P at the rate of 0 kg ha^{-1} resulted in the lowest number of effective tillers plant^{-1}.

3.4. Number of Pods per Plant

Faba bean varieties were significantly ($P<0.05$) affected number of pods plant^{-1} of faba bean (Table 2). Higher number of pods plant^{-1} (17) was recorded from Dosha variety, which was statistically not at par from that of Tumsa variety (16) (Table 2). Lower number of pods plant^{-1} (15) was recorded from Gebelcho variety. Likewise, [33] reported that number of pods plant^{-1} were affected by faba bean varieties and found Gebelcho variety had the smallest number of pods plant^{-1}. This result is also in line with [29] who reported that Degaga varieties had a higher number of pods per plant, while Gebelcho and Moti varieties had the smallest number of pods per plant.

The effect of different levels of phosphorus fertilizer on the number of pods plant^{-1} was not significant (P>0.05) (Table 2). This result was disagreeing with [34] who reported that, the number of pods per plant was significantly influenced by application of P. In contrary, on common bean [35] who indicated that all applied P fertilizer rates significantly increased pods per plant over the control and significantly higher number of pods per plant was recorded with P rates of 20 kg ha^{-1} over rest of the levels. Similarly, [36] also found that faba bean did not respond to phosphorus application in terms of pod number plant^{-1}. The pod number plant^{-1} is a genetic character and is less influenced by the environment in terms of plant density and P nutrition.

3.5. Number of Seeds per Pod

The mean number of seeds pod^{-1} of faba bean is indicated in Table 2. Neither all the main effects of faba bean varieties and P fertilizer rates nor their interaction had non -significant (P>0.05) effect on the number of seeds pod^{-1} of faba bean. Similarly, [37] found that different levels of P application on faba bean did not significantly affect the number of seeds per pod. As [36] reported number of seeds pod^{-1} did not vary significantly among the genotypes, while it tended to vary with plant density and phosphorus nutrition. In contrary, [36] found that phosphorus application tended to improve seeds pod^{-1} when compared with no phosphorus.

3.6. Thousand Seed weight

The mean thousand seed weight is indicated in Table 2. Mean thousand seed weight was highly significantly (P<0.001) affected by main effect of faba bean varieties. Significantly higher mean values of thousand seed weight (790 g) was recorded from Gebelcho variety which was statistically at par with Tumsa variety (777 g), whereas, the lower average thousand grain weight (699 g) was obtained from Dosha variety. This might be due to fact that Gebelcho variety is larger in seed size as compared to the other varieties even though all the three varieties are large seeded beans. Similarly, [33] reported that Gebelcho and Hacalu varieties had the highest average thousand grain weights whereas, the lowest average 1000 grain weight was recorded from Degaga and Shallo faba bean varieties.   As [38] reported that Moti, Tumsa and Gebelcho varieties had higher thousand grain weight while Degaga variety was smaller 1000 grain weight. According to [39] reported 1000 weight of Degaga variety was similar to Shallo variety and it was small. Mean thousand seed weight of faba bean was non-significant (P>0.05) affected by main effect of different rates of P fertilizer and its interaction with varieties (Table 2). This result is in line with [34] who suggested that effect of phosphorus application on 1000 grain weight was not significant. As [40] suggested application of P at 0-60 kg ha^{-1} contributes to nutrient absorption (phosphorus, potassium, magnesium and zinc) caused by the increase in soluble phosphorus and assimilation of nutrients to the grain, resulting in larger grains. This could be the reason for the increased thousand grain weight. At low fertilizer treatments, a decrease in 1000-grain weight resulted from the competition for nutrients and the decrease in carbohydrate stores. Increased soluble P content increased the amount of phytin stored in the seeds. Phytin serves as the main source of stored P in most grains and is an important compound for germination and seed growth with a significant contribution to seed size and weight [34]. According to [31] phosphorus being responsible for good root growth directly affected the thousand grain weight because P at the rate of 0 kg ha^{-1} (control plots) resulted in the least thousand grain weight. In contrary, [41] found that the application of FYM and P fertilizer had significantly ($P<0.05$) influenced thousand seeds weight of faba bean.

3.7. Harvest Index

The mean harvest index of faba bean is indicated in Table 3. Harvest index was significantly ($P<0.001$) affected by different faba bean varieties (Table 3). Significantly higher mean harvest index of (49%) was obtained from Gebelcho variety which was statistically at par with that of Dosha variety (48%), Tumsa variety resulted low (44%) harvest index. Higher thousand seed weight producing variety has a higher harvest index. This indicated that harvest index might differ between genotypes. Similarly, [33] reported that harvest index of faba bean had significantly affected on faba bean varieties. As [42] also reported harvest index varies for different faba bean varieties.

Mean harvest index of faba bean was non- significantly affected with levels of P application and its interaction with varieties showed significant effects on harvest index of faba bean. Similarly, [43] found that P application rates had non-significant effects for harvest index of faba bean. According to [44] reported that harvest index of faba bean decreased by application of P at 20 kg P ha^{-1} due to enhanced straw production. In contrary, [45] reported that there was a significant difference in ($P\leq0.05$) of the interaction between treatments of biological phosphorus, mineral phosphorus and nitrogen on harvest index.

3.8. Dry Biomass Yield

The mean dry biomass yield of faba bean is indicated in Table 3. Main effect of varieties and phosphorus rates were highly significantly ($P<0.001$) affected the dry biomass yield of faba bean, whereas, the interaction of both variety and P rates was non-significantly ($P>0.05$) affected dry biomass yield of faba bean. Significantly higher mean value of dry biomass yield of (13905 kg ha^{-1}) was obtained from Tumsa variety whereas, lower mean value of dry biomass yield (12153 kg ha^{-1}) was obtained from Gebelcho variety which is statistically at par with Dosha (12559 kg ha^{-1}). Likewise, [33] reported that dry matter biomass had significant different on faba bean varieties. This result also in agreement with [42] who reported that dry biomass was significantly varies with faba bean varieties.

Mean dry biomass yield of faba bean was highly significantly ($P<0.001$) affected by different levels of phosphorus fertilizer (Table 3). Significantly higher mean dry biomass yield of (14158 kg ha^{-1}) was produced with application of 40 kg P ha^{-1} that was at par with 20 kg P ha^{-1} and 30 kg P ha^{-1} respectively. The lower dry biomass yield (10970 kg ha^{-1}) was obtained from 0 kg P ha^{-1} followed by application of 10 kg ha^{-1}(12092 kg ha^{-1}). As phosphorus levels increase from 0 kg P ha^{-1} to 40 kg P ha^{-1} the dry biomass yield was increased by 29% (Table 3). Similarly, [41] found that the application of FYM and P fertilizer had significant ($P<0.05$) influenced biomass yield of faba bean.

Since phosphorus is responsible for good root growth and development it directly affects the overall plant performance, as a result a good and optimum supply of P is important for crops to explore more soil nutrients and moisture. This is why the above ground dry biomass yield was the lowest in the control plots because lack of P impacts the roots growth of the plants which in turn negatively affected the other physiological functions of the faba bean plants in the control plots. As observed from the mean values of the data indicated in Table 3 dry biomass accumulation increases with application of phosphorus fertilizer rates. This increment in above ground dry biomass yield with application of P fertilizer might be due to supplying adequate of P could be contributed to an increase in number of pods, plant height, leaf area and other crop physio-morphology.

3.9. Grain Yield

The mean grain yield of faba bean is indicated in Table 3. Main effect of varieties had non-significant (P>0.05) effect on mean grain yield of faba bean. In contrary [33] reported that there was a variation between the varieties for most yield and yield components including grain yield. Interaction effect of faba bean varieties and P application rates also did not influence grain yield significantly (P>0.05). Application of different levels of phosphorus had a highly significant (P<0.001) effect on mean grain yield of faba bean. Application of 40 kg ha $^{-1}$ resulted in higher grain yield (6323 kg ha^{-1}), which was statistically at par with P applied at the rates of 20 kg P ha^{-1} and 30 kg P ha^{-1}. All applied P fertilizer rates significantly increased grain yield of faba bean over the control. The lowest gain yield (5076 kg ha^{-1}) was recorded from control. As phosphorus rates increased from 0 kg ha^{-1} to 40 kg ha^{-1} the grain yield of faba bean increased by 25%. This increase in yield is therefore, attributed to the increased available P due to P fertilizers application. As phosphorus rates increased from 0 kg ha^{-1} to 40 kg ha^{-1} progressive increases in mean grain yield of faba bean. This increase in grain yield might be attributed due to P fertilizer application which indicates that the soil of the experimental field is low in available P. This finding is agreed with [41] who found that the application of FYM and P fertilizer on yield parameters of faba bean had positively (P <0.05) influenced such as biomass, grain yield, straw weight and thousand seeds weight. Similarly, [36] reported fertilization of faba bean with resulted in substantial increase in seed and biological yields over no fertilizer. These results agree with [46] who reported that grain yield of faba bean was significantly affected by different levels of phosphorous.

3.10. Effect of Phosphorus Fertilizer on Economic Feasibility of Faba bean Production

The highest net benefit of ETB 60,225 ha^{-1} was obtained from the application of 40 kg P ha^{-1} followed by application of 30 kg P ha^{-1} (ETB 59,689 ha^{-1}), 20 kg P ha^{-1} (ETB 56,551 ha^{-1}) and 10 kg Pha^{-1} (ETB 52,215 ha^{-1}) (Table 4). Higher marginal rate of return of 1,404 % was obtained with application of 10 kg P ha^{-1} followed by 20 and 30 kg P ha^{-1} with marginal rate of return of 694 and 502% (Table 4). The value to cost ratio was ranged from 1.26 to 1.64 profits per unit of investment. Therefore, application of 20 kg P ha^{-1} was economical feasible and recommended for faba bean production in Lemu bilbilo district of Arsi.

4. CONCLUSIONS

Application of 20 kg P ha^{-1} was proved to be productive and economical feasible for faba bean production and be recommended for faba bean production in the study area and similar agro-ecologies. However, this study should be repeated both over locations and years in order to give complete recommendation for practical application.

DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Table 1. Initial selected physico-chemical characteristics of soils for the experimental sites

Soil parameters	Value	Rating	Reference
pH (1: 2.5 H_2O)	4.51	Strongly Acidic	[38]
Available Phosphorus (mg kg $^{-1}$)	0.7	Very Low	[20]
Exch. Acidity (cmolc kg^{-1})	2.72		
Organic Carbon (%)	1.33	Low	[38]
CEC (cmolc kg^{-1})	14.1	Low	[26]
Total Nitrogen (%)	0.18	Moderate or Medium	[38] and [26]
Exch. Calcium (cmolc kg^{-1})	7.7	Medium	[27]
Exch. Magnesium (cmolc kg^{-1})	1.68	Medium	[27]
Exch. Sodium (cmolc kg^{-1})	0.47	Medium	[27]
Exch. Potassium (cmolc kg^{-1})	1.23	Very High	[27]
Bulk Density(g cm^{-3})	1.39	Moderate	[28]
Sand (%)	Silt (%)	Clay (%)	Textural Class
25.36	41.50	33.14	Clay loam

Table 2.Main effect of varieties and phosphorus rates on plant height, total productive tillers plant^{-1}, number of pods plant^{-1}, number of seed pod^{-1} and thousand seed weight of faba bean

Treatments	Plant height (cm)	Productive tillers plant^{-1}	Number of pods plant^{-1}	Number of seed pod^{-1}	Thousand seed weight (g)
Varieties					
Tumsa	156.87^{a}	1.27^{b}	16^{ab}	3	777^{a}
Gebelcho	137.87^{b}	1.53^{a}	15^{b}	3	790^{a}
Dosha	140.80^{b}	1.40^{ab}	17^{a}	3	699^{b}
LSD (5%)	5.68	0.16	1.64	NS	20.86
Phosphorus rate (kg ha^{-1})					
0	134.10^{c}	1.18^{b}	16	3	747
10	140.89^{bc}	1.36^{ab}	17	3	759
20	147.33^{ab}	1.49^{a}	16	3	768
30	150.67^{a}	1.53^{a}	16	3	759

40	152.89^{a}	1.44^{a}	17	3	743
LSD (5%)	7.34	0.21	NS	NS	NS
CV (%)	5.2	15.3	13.4	12	3.7

Means within a column followed by the same letter are not significantly different at 1 and 5% probability level, NS = Not significant at 5% and 1% probability level respectively.

Table 3. Main effects of varieties and phosphorus rates on harvest index, above ground biomass yield and grain yield of faba bean

Varieties	Harvest Index (%)	Dry biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Tumsa	43.84^{b}	13905^{a}	5924
Gebelcho	48.53^{a}	12153^{b}	5748
Dosha	48.47^{a}	12559^{b}	5937
LSD (0.05)	2.17	789.53	NS
Phosphorus rate (kg ha^{-1})			
0	47.66	10970^{c}	5076^{c}
10	48.43	12092^{b}	5693^{b}
20	46.92	13178^{a}	6008^{ab}
30	46.04	13962^{a}	6248^{a}
40	45.67	14158^{a}	6323^{a}
LSD (0.05)	NS	1019	463
CV (%)	6.2	8.2	8.17

Means within a column followed by the same letter are not significantly different at 1 and 5 % probability level. NS = Not significantly different at 5% and 1% probability level respectively.

Table 4. Effects of phosphorus fertilizer rates on economic feasibility of faba bean production

Phosphorus rates (kg P ha^{-1})	Average Yield (kg ha^{-1})	Adjusted Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Total Gross Benefit (ETB ha^{-1})	TVC (EBha^{-1})	Net Benefit (ETB)	Values to cost ratio	MRR (%)
0	5219	5076	5894	77913	34475	43438	1.26	
10	5813	5693	6399	87315	35100	52215	1.49	1404
20	6159	6008	7170	92276	35725	56551	1.58	694
30	6395	6248	7713	96039	36350	59689	1.64	502
40	6431	6323	7834	97200	36975	60225	1.63	86

Faba bean seeds = 20.20 Birr kg ha^{-1}, Urea = 1150 Birr 100 kg^{-1}, TSP = 1250 Birr 100 kg^{-1}, Faba bean grain = 1500 Birr 100 kg^{-1},