

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 TSP. 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 1,404,694 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 [23]. 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 [36]. 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 [30]. 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 N₂ fixation for growth [2]. The use of faba bean crop rotation had a significant effect by reducing the amount of chemical nitrogen applied to soil for crop production [50]. The straw of faba bean is also used as animal feed and soil fertility restorer [32]. The average national productivity of faba bean is 2.1 t ha⁻¹ but, is low as compared to the world top producers [23]. As [51] 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. In addition to this, its production in Ethiopia is limited and

46 fails to satisfy the increasing local consumption of seeds due to gradual decreases in its average yield. So,
47 increasing crop production is the major target of the national agriculture policy and can be achieved by
48 growing high yielding and stable cultivars under favorable environmental conditions [7].

49 According to [4] reported that improved agronomic practices increased the grain yields by 88% over the
50 yields of conventional farmers' practices. Besides, different varieties have different responses to inputs of
51 production. Substantial yield differences between researcher and farmers managed trials are known to occur
52 due to crop management applied and input use and other environmental factors. However, improper use of
53 inorganic fertilizer is one of the main causes of environmental degradation in Africa [11]. Low and
54 unbalanced application rates per unit area of land mainly focusing on Urea and DAP fertilizers with low
55 efficiency of the fertilizers [30] and limited use of improved seeds [24] have still remained major constraints
56 for small farmers to get the best out of the input.

57 The lack or low rates of essential elements like P in the soil is one of the factors negatively affect growth and
58 yields of faba bean. Phosphate can readily be rendered unavailable to plant roots as it is the most immobile of
59 the major plant nutrients. In spite of the considerable addition of phosphorus to soil, the amount available for
60 plant is usually low. Phosphorus fertilization has positive effect on faba bean yield and yield components
61 [26]. The high variability of productivity among smallholder farmers can be attributed to soil characteristics,
62 quality of field management, input use, geophysical characteristics such as altitude and weather conditions,
63 demographic and market situations [3]. The use of mineral fertilizers to increase faba bean productivity by
64 Ethiopian farmers is also low and this makes the farmers to produce faba bean below its potential.

65 Faba bean is also a very important crop in the Arsi zone grown to break the monoculture wheat-based
66 farming system that always suffers from attacks by new races of rust with significant yield reductions. In
67 Ethiopia research work regarding use of P and its role in legume growth, nodulation, N₂ fixation and grain
68 yield and yield components is very limited. Inclusion of this crop in the crop rotation system with the
69 application of optimum phosphorus fertilizer which is a limiting factor for the production of faba bean is
70 crucial in the highlands like study area. Indeed, testing of the alternative technology for different varieties is
71 very essential to assess its feasibility and ascertain the response of improved varieties to inputs of production
72 in the region. Therefore, the objective was to determine the response of faba bean varieties to different rates
73 of phosphorus fertilizer rates on yield and yield components of faba bean in Lemu Bilbilo district.

74 **2. MATERIALS AND METHODS**

75 ***2.1. Description of the Study Area***

76 Field experiment was conducted in Lemu Bilbilo district, Arsi Zone of Oromia Regional National State,
77 South eastern Ethiopia in 2017 main cropping season. Lemu Bilbilo lies between 7.55 °N and 8.26 °N latitude
78 and 39.23°E and 39.26 °E longitude at an altitude of 2780 meters above sea level with the agro-ecology of
79 sub-humid tropics and high rain fall. The average mean minimum and maximum temperature are 7.9 and
80 18.6 °C respectively. It receives mean annual rainfall of 1020 mm with quasi bi-modal distribution and
81 maximum (202 mm) occurs in August (KARC, unpublished). The soils of the study area are classified
82 Nitisols with the pH of 5.0 [14].

83 **2.2. Treatments and Experimental Design**

84 Factorial combinations of three faba bean varieties (Tumsa, Gebelcho and Dosha) and five phosphorus levels
85 (0, 10, 20, 30 and 40 kg P ha⁻¹) from TSP were used for the experiment. The experiment was laid out in a
86 randomized complete blocked design with 3 x 5 factorial arrangements with three replications. The seed rate
87 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
88 m²) and 2.6 x 2.4 m (6.24 m²). Triple Super Phosphate and urea were used as source of phosphorus and
89 nitrogen respectively. Faba bean seeds were sown in row with 40 cm inter rows and 10 cm intra row spacing.
90 Applications of different rates of phosphorus fertilizer as Triple superphosphate were done in the rows of
91 faba bean seed once at planting. Nitrogen (18 kg N ha⁻¹) fertilizer was applied as urea uniformly at sowing in
92 rows of faba bean and mixed to soil and improved agronomic management practices (weeding, hoeing,
93 disease management etc.) was applied for faba bean during the growing period.

94 **2.3. Soil Sampling, Preparation and Analysis**

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

103

104 Undisturbed surface soil sample was collected using core sampler from the experimental field to determine
105 bulk density of the soil before planting. The soil core was removed from undisturbed soil by driving the
106 cylinder into the soil with block of wood and hammer. The soil core was examined and the ends were
107 trimmed carefully. Then the soil and the cylinder were weighed; the weight of the soil sample alone was
108 calculated by subtracting the weight of the cylinder. Portion of the soil was taken for determination of soil
109 moisture and the oven-dry weight of the sample was calculated. Lastly, the bulk density (gcm⁻³) of the soil
110 was calculated from weight of oven dry soil core (g) and volume of soil core (cm³) [29].

111 Soil texture was determined using the Bouyoucos hydrometer method [16] and organic matter content was
112 determined by the oxidation of organic carbon with acid potassium di-chromate (K₂Cr₂O₇) medium using the
113 Walkley and Black method as described by [25]. The pH of the soil was measured or determined by using
114 potentiometric method at 1:2.5 (weight/ volume) soil to water dilution ratio using a glass electrode attached
115 to digital pH meter [43]. Total nitrogen was determined by using Kjeldahl method as described by [37] and
116 also available phosphorus was determined by using the Bray II method [17]. Cation exchange capacity (CEC)
117 was measured after saturating the soil with 1N ammonium acetate (NH₄OAC) and displacing it with 1N
118 NaOAC and was determined from ammonium acetate saturated samples that was subsequently replaced by
119 Na from a percolated sodium chloride solution [19]. The excess salt was removed by washing with alcohol
120 and the ammonium that was replaced by sodium was measured by using the Kjeldahl method as described by
121 [44]. Exchangeable bases were extracted with 1M ammonium acetate at pH 7.0. Exchangeable Ca and Mg

122 were measured from the extract with atomic absorption spectrophotometry while exchangeable K and Na
123 were determined from the same extract with flame photometry. Total exchangeable acidity was determined
124 by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as
125 described by [40].

126 **2.4. Data Collection**

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

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

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

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

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

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

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

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

144 *Harvest index:* was computed as a ratio of seed yield (kg ha⁻¹) to dry biomass yield (kg ha⁻¹) *100.

145 **3. RESULTS AND DISCUSSION**

146 **3.1. Some Soil Physico-chemical Properties of the Experimental Site**

147 The soil texture distribution of the experimental site was clay loam (Table 1). The soil reaction of the
148 experimental sites is strongly acidic [49] rating. This indicates that the soil experimental site requires soil
149 amendment with lime to make it suitable for optimum growth and yield of most crops. The available P level
150 was (0.7 mg kg⁻¹ of soil) (Table 1) which is found in very low range as [20]. This indicates that the available
151 P of the study area is very low which point us P fertilizer application is crucial for the study area in order to
152 maximize faba bean production. The low available phosphorus could be due to P fixation in such acidic soils
153 and removal of basic cations such as Ca²⁺, Mg²⁺, Na⁺ and K⁺ from the top soil because of high rain fall of the
154 area. The total nitrogen percentage of the experimental field was 0.18% (Table 1) and found in low range
155 [49]. The cation exchange capacity of the experimental soil was 14.1cmol (+) kg⁻¹ which is found in low
156 range [13]. The total carbon content in the soils was 1.33%. The concentrations of exchangeable Ca (7.7
157 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
158 cmolc kg⁻¹) which was high. The bulk density of the soils of the experimental site is 1.39 g/cm³.

159 **3.2. Plant Height**

160 The mean plant height of faba bean is indicated in Table 2. The main effect of faba bean varieties had a
161 highly significant ($P < .001$) effect on plant height of faba bean. Significantly higher mean plant height of (157
162 cm) was recorded from Tumsa variety whereas, variety Gebelcho resulted shortest (138 cm) stature plants
163 followed by Dosha variety (141 cm). Gebelcho variety is considered as dwarf variety as compared to the
164 other two varieties. Likewise, [46] reported that a variety called Gebelcho was the shortest variety. According
165 to [47] also reported that plant height was significantly affected by faba bean accessions. Application of
166 different rates of phosphorus had highly significant ($P = .05$) effect on plant height of faba bean (Table 2).
167 Application of 40 kg P ha⁻¹ resulted in long stature plants (153 cm) followed by 30 kg P ha⁻¹ (151 cm). The
168 short stature plants (145 cm) were observed in control plots followed by application of P at 10 kg P ha⁻¹.
169 Phosphorus application at the rate of 40 kg P ha⁻¹ might be the optimum rate to trigger an increase in plant
170 height with per unit increase in phosphorus rate as deduced from the control plots. As P levels increase from
171 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
172 higher P level on plant height was probably due to better development of root system and nutrient absorption
173 [34]. Likewise, [52] reported an increase in plant height of faba bean both at 50% flowering and maturity
174 stage in response to increased P application.

175 **3.3. Total Productive Tillers plant⁻¹**

176 The main effect of faba bean varieties had highly significant ($P < .001$) effect on total number of effective
177 tillers plant⁻¹ (Table 2). Significantly higher number of effective tillers plant⁻¹ (1.53) was recorded from
178 Gebelco variety, whereas, the lowest number of effective tillers plant⁻¹ was obtained from Tumsa variety
179 which is as par statistically Dosha variety (Table 2). This might be due to variation in genotype of the faba
180 bean varieties. In contrary, [9] found that faba bean varieties had no significant effect on number of tillers
181 plant⁻¹. The effect of different levels of P on number of effective tiller plant⁻¹ showed significant ($P = .05$)
182 difference for faba bean (Table 2). The application of 30 kg P ha⁻¹ resulted in higher number of effective
183 tillers plant⁻¹ (1.53), which was at par with all other p rates application except the control (1.18). This
184 indicated that P at the rate of 30 kg ha⁻¹ might be the optimum rate for improvement of number of effective
185 tiller plant⁻¹ that ultimately had directly affected grain yield of faba bean. Further increase in P rate above 30
186 kg ha⁻¹ did not have a linear effect on the number of effective tillers plant⁻¹ of faba bean which is obvious
187 from the plots with P applied at the rate of 40 kg ha⁻¹ that had less number of effective tiller plant⁻¹ even
188 though both treatments were statistically at par. As P is responsible for good root growth which directly
189 affects the overall plant performance, the regimes of P at the rate of 0 kg ha⁻¹ resulted in the lowest number of
190 effective tillers plant⁻¹.

191 **3.4. Number of Pods Plant⁻¹**

192 Faba bean varieties were significantly ($P = .05$) affected number of pods plant⁻¹ of faba bean (Table 2).
193 Higher number of pods plant⁻¹ (17) was recorded from Dosha variety, which was statistically not at par from
194 that of Tumsa variety (16) (Table 2). Lower number of pods plant⁻¹ (15) was recorded from Gebelcho variety.
195 Likewise, [9] reported that number of pods plant⁻¹ were affected by faba bean varieties and found Gebelcho
196 variety had the smallest number of pods plant⁻¹. This result is also in line with [46] who reported that Degaga

197 varieties had a higher number of pods per plant, while Gebelcho and Moti varieties had the smallest number
198 of pods per plant.

199 The effect of different levels of phosphorus fertilizer on the number of pods plant⁻¹ was not significant
200 ($P>.05$) (Table 2). This result was disagreeing with [42] who reported that, the number of pods per plant was
201 significantly influenced by application of P. In contrary, on common bean [41] who indicated that all applied
202 P fertilizer rates significantly increased pods per plant over the control and significantly higher number of
203 pods per plant was recorded with P rates of 20 kg ha⁻¹ over rest of the levels. Similarly, [38] also found that
204 faba bean did not respond to phosphorus application in terms of pod number plant⁻¹. The pod number plant⁻¹
205 is a genetic character and is less influenced by the environment in terms of plant density and P nutrition.

206 **3.5. Number of Seeds Pod⁻¹**

207 The mean number of seeds pod⁻¹ of faba bean is indicated in Table 2. Neither all the main effects of faba
208 bean varieties and P fertilizer rates nor their interaction had non -significant ($P>.05$) effect on the number of
209 seeds pod⁻¹ of faba bean. Similarly, [15] found that different levels of P application on faba bean did not
210 significantly affect the number of seeds per pod. As [38] reported number of seeds pod⁻¹ did not vary
211 significantly among the genotypes, while it tended to vary with plant density and phosphorus nutrition. In
212 contrary, [38] found that phosphorus application tended to improve seeds pod⁻¹ when compared with no
213 phosphorus.

214

215 **3.6. Thousand Seed weight**

216 The mean thousand seed weight is indicated in Table 2. Mean thousand seed weight was highly significantly
217 ($P<.001$) affected by main effect of faba bean varieties. Significantly higher mean values of thousand seed
218 weight (790 g) was recorded from Gebelcho variety which was statistically at par with Tumsa variety (777
219 g), whereas, the lower average thousand grain weight (699 g) was obtained from Dosha variety This might be
220 due to fact that Gebelcho variety is larger in seed size as compared to the other varieties even though all the
221 three varieties are large seeded beans. Similarly, [9] reported that Gebelcho and Hacalu varieties had the
222 highest average thousand grain weights whereas, the lowest average 1000 grain weight was recorded from
223 Degaga and shallo faba bean varieties. As [48] reported that Moti, Tumsa and Gebelcho varieties had higher
224 thousand grain weight while Degaga variety was smaller 1000 grain weight. According to [31] reported 1000
225 weight of Degaga variety was similar to Shallo variety and it was small. Mean thousand seed weight of faba
226 bean was non-significant ($P>.05$) affected by main effect of different rates of P fertilizer and its interaction
227 with varieties (Table 2). This result is in line with [42] who suggested that effect of phosphorus application
228 on 100 grain weight was not significant. As [53] suggested application of P at 0-60 kg ha⁻¹ contributes to
229 nutrient absorption (phosphorus, potassium, magnesium and zinc) caused by the increase in soluble
230 phosphorus and assimilation of nutrients to the grain, resulting in larger grains. This could be the reason for
231 the increased thousand grain weight. At low fertilizer treatments, a decrease in 1000-grain weight resulted
232 from the competition for nutrients and the decrease in carbohydrate stores. Increased soluble P content
233 increased the amount of phytin stored in the seeds. Phytin serves as the main source of stored P in most

234 grains and is an important compound for germination and seed growth with a significant contribution to seed
235 size and weight [42]. According to [34] Phosphorus being responsible for good root growth directly affected
236 the thousand grain weight because P at the rate of 0 kg ha⁻¹ (control plots) resulted in the least thousand grain
237 weight. In contrary, [45] found that the application of FYM and P fertilizer had significantly ($P=0.05$)
238 influenced thousand seeds weight of faba bean.

239 **3.7. Harvest Index**

240 The mean harvest index of faba bean is indicated in Table 3. Harvest index was significantly ($P<0.001$)
241 affected by different faba bean varieties (Table 3). Significantly higher mean harvest index of (49%) was
242 obtained from Gebelcho variety which was statistically at par with that of Dosha variety (48%), Tumsa
243 variety resulted low (44%) harvest index. Higher thousand seed weight producing variety has a higher
244 harvest index. This indicated that harvest index might differ between genotypes. Similarly, [9] reported that
245 harvest index of faba bean had significantly affected on faba bean varieties. As [1] also reported harvest
246 index varies for different faba bean varieties.

247 Mean harvest index of faba bean was non- significantly affected with levels of P application and its
248 interaction with varieties showed significant effects on harvest index of faba bean. Similarly, [6] found that P
249 application rates had non-significant effects for harvest index of faba bean. According to [5] reported that
250 harvest index of faba bean decreased by application of P at 20 kg P ha⁻¹ due to enhanced straw production. In
251 contrary, [10] reported that there was a significant difference in ($P\leq 0.05$) of the interaction between treatments
252 of biological phosphorus, mineral phosphorus and nitrogen on harvest index.

253 **3.8. Dry Biomass Yield**

254 The mean dry biomass yield of faba bean is indicated in Table 3. Main effect of varieties and phosphorus
255 rates were highly significantly ($P<0.001$) affected the dry biomass yield of faba bean, whereas, the interaction
256 of both variety and P rates was non-significantly ($P>0.05$) affected dry biomass yield of faba bean.
257 Significantly higher mean value of dry biomass yield of (13905 kg ha⁻¹) was obtained from Tumsa variety
258 whereas, the lowest mean value of dry biomass yield (12153 kg ha⁻¹) was obtained from Gebelcho variety
259 which is statistically at par with Dosha (12559 kg ha⁻¹). Likewise, [9] reported that dry matter biomass had
260 significant different on faba bean varieties. Higher mean dry biomass weight (11470 Kg ha⁻¹) was recorded
261 from Tumsa variety. This result also in agreement with [1] who reported that reported that dry biomass was
262 significantly varies with faba bean varieties.

263 Mean dry biomass yield of faba bean was highly significantly ($P<0.001$) affected by different levels of
264 phosphorus fertilizer (Table 3). Significantly higher mean dry biomass yield of (14158 kg ha⁻¹) was produced
265 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
266 biomass yield (10970 kg ha⁻¹) was obtained from 0 kg P ha⁻¹. As phosphorus levels increase from 0 kg P ha⁻¹
267 to 40 kg P ha⁻¹ the dry biomass yield was increased by 29% (Table 3). Similarly, [45] found that the
268 application of FYM and P fertilizer had significant ($P<0.05$) influenced biomass yield of faba bean.

269 Since phosphorus is responsible for good root growth and development it directly affects the overall plant
270 performance, as a result a good and optimum supply of P is important for crops to explore more soil nutrients

271 and moisture. This is why the above ground dry biomass yield was the lowest in the control plots because
272 lack of P impacts the roots growth of the plants which in turn negatively affected the other physiological
273 functions of the faba bean plants in the control plots. As observed from the mean values of the data indicated
274 in Table 3 dry biomass accumulation increases with application of phosphorus fertilizer rates. This increment
275 in above ground dry biomass yield with application of P fertilizer might be due to supplying adequate of P
276 could be contributed to an increase in number of pods, plant height, leaf area and other crop physio-
277 morphology.

278 **3.9. Grain Yield**

279 The mean grain yield of faba bean is indicated in Table 3. Main effect of varieties had non-significant
280 ($P>.05$) effect on mean grain yield of faba bean. In contrary [9] reported that there was a variation between
281 the varieties for most yield and yield components including grain yield. Interaction effect of faba bean
282 varieties and P application rates also did not influence grain yield significantly ($P>.05$). Application of
283 different levels of phosphorus had a highly significant ($P<.001$) effect on mean grain yield of faba bean.
284 Application of 40 kg ha⁻¹ resulted in higher grain yield (6323 kg ha⁻¹), which was statistically at par with P
285 applied at the rates of 20 kg P ha⁻¹ and 30 kg P ha⁻¹. All applied P fertilizer rates significantly increased grain
286 yield of faba bean over the control. The lowest gain yield (5076 kg ha⁻¹) was recorded from control. As
287 phosphorus rates increased from 0 kg ha⁻¹ to 40 kg ha⁻¹ the grain yield of faba bean increased by 25%. This
288 increase in yield is therefore, attributed to the increased available P due to P fertilizers application. As
289 phosphorus rates increased from 0 kg ha⁻¹ to 40 kg ha⁻¹ progressive increases in mean grain yield of faba
290 bean. This increase in grain yield might be attributed due to P fertilizer application which indicates that the
291 soil of the experimental field is low in available P. This finding is agreed with [45] who found that the
292 application of FYM and P fertilizer on yield parameters of faba bean had positively ($P=.05$) influenced such
293 as biomass, grain yield, straw weight and thousand seeds weight. Similarly, [38] reported fertilization of faba
294 bean with resulted in substantial increase in seed and biological yields over no fertilizer. These results agree
295 with [39] who reported that grain yield of faba bean was significantly affected by different levels of
296 Phosphorous.

297 **3.10. Effect of Phosphorus Fertilizer on Economic Feasibility of Faba bean Production**

298 The highest net benefit of ETB 60,225 ha⁻¹ was obtained from the application of 40 kg P ha⁻¹ followed by
299 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 P ha⁻¹ (ETB 52,215
300 ha⁻¹) (Table 4). Higher marginal rate of return of 1,404 % was obtained with application of 10 kg P ha⁻¹
301 followed by 20 and 30 kg P ha⁻¹ with marginal rate of return of 694 and 502% (Table 4). The value to cost
302 ratio was ranged from 1.26 to 1.64 profits per unit of investment. Therefore, application of 20 kg p ha⁻¹ was
303 economical feasible and recommended for faba bean production in Lemu bilbilo district of Arsi.

304 **4. CONCLUSIONS**

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

309 **COMPETING INTERESTS**

310 Authors have declared that no competing interests exist.

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442

443

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

Soil Parameters	Value	Rating	Reference
pH (1: 2.5 H ₂ O)	4.51	Strongly Acidic	[48]
Available Phosphorus (mg kg ⁻¹)	0.7	Very Low	[17]
Exch. Acidity (cmolc kg ⁻¹)	2.72		
Organic Carbon (%)	1.33	Low	[48]
CEC (cmolc kg ⁻¹)	14.1	Low	[13]
Total Nitrogen (%)	0.18	Moderate or Medium	[48] and [13]
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	[33]
Sand (%)	Silt (%)	Clay (%)	Textural Class
25.36	41.50	33.14	Clay loam

445

446 Table 2. Main effect of varieties and phosphorus rates on plant height, total productive tillers plant⁻¹, number
447 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 plant ⁻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

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

450

451 Table 3. The main effects of varieties and phosphorus rates on harvest index, above ground biomass yield and
452 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

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

455

456 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

457 Faba bean seeds = 20.20 kg ha⁻¹, Urea = 1150 Birr 100 kg⁻¹, TSP = 1250 Birr 100 kg⁻¹, Faba bean grain =
458 1500 Birr 100 kg⁻¹,
459

UNDER PEER REVIEW