RESEARCH ARTICLE

Effect of faba bean (*Vicia faba* L.) genotypes, plant densities and phosphous on productivity, nutrients uptake, soil fertility changes and economics in Central high lands o Ethiopia

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ABSTRACT

A field experiment was conducted at Ambo University research farm with the objective to determine the optimum P rate and population densities in faba bean (*Vicia faba* l.) genotypes grown on vertisols. The treatments comprised three genotypes (Hachalu, Walki and Local), three spacings (30 cmx7.5 cm, 40 cmx5.0 cm and 60 cmx5.0 cm) and two phosphorus levels (0 kg p_20_5/ha and 46 kg p_20_5/ha,) which were laid out in a split- split plot design with three replications. The results showed that the improved genotype, Walki (3,407 kg/ha) was comparable with Hachalu (3,037 kg/ha) and gave substantially greater seed yield than the local cultivar (2,833 kg/ha). Seeding at 44 plants/m^2 resulted in substantially higher seed and biological yields (3,815 kg/ha and 7,894 kg/ha) than 50 plants/m^2 (3,074 kg/ha and 6,570 kg/ha) and 33 plants/m^2 (2,388 kg/ha and 4,696 kg/ha); although the harvest index was unaltered. Fertilization of faba bean with 46 kg p_20_5/ha resulted in substantial increase in seed (3,531 kg/ha) and biological yields (7,172 kg/ha) over no fertilizer check (2,654 kg/ha seed and 5,602 kg/ha haulm yield). The harvest index tended to improve with p nutrition (49.7) over no phosphorus (47.4). Correlations worked between yield and growth and yield components showed a significant positive relation between seed yield and plant height at different stages, leaf area/plant, leaf area index, biological yield and seed yield/plant. Biomass yield is correlated with leaf area/plant, leaf area index, and plant height. Nutrient (np) removal of genotypes both in seed and haulm has been greater in Walki and Hachalu than in the local cultivar. The n removal in seed and haulm of Walki was 107 kg/ha and 58 kg/ha; and the corresponding removal of Hachalu was 95 kg/ha and 52 kg/ha; while that of the local cultivar was 89 kg/ha and 48 kg/ha. The n uptake in seed and haulm has been greater with 44 plants/m^2 (120 kg/ha and 66 kg/ha) in comparison with 50 plants/m^2 (97 kg/ha and 54 kg/ha) and 33 plants/m² (75 kg/ha and 37 kg/ha). The uptake of p in seed and haulm increased with p application (11.3 kg/ha and 3.6 kg/ha) over no p-application (8.5 kg/ha and 2.7 kg/ha). In protein yield, Walki and Hachalu were better than the local variety. Maintaining 44 plants/m^2 performed better than 50 and 33plants/m^2. Application of 46 kgp_2o_5/ha out yielded no P check. Nutrient dynamics of soil after harvest of crop showed that there was an increase in soil N status ranging from 0.00 to 0.05 percent but a sharp decline in soil P and K contents after the crop harvest due to greater removal by the crop, which ranged from 4.03 to 4.27 ppm of P and 0.15 to 0.01 meq/100g of K. Economic analysis of the genotypes showed that Walki gave the highest net returns (ETB 29,642/ha) followed by Hachalu (ETB 24,827/ha) and the local cultivar (ETB 22,178/ha). Maintaining 44 plants/m^2 gave higher net return (ETB 34,938/ha) than 50 plants/m^2 (ETB 25,309/ha) and 33 plants/m^2 (ETB 16,401/ha). Phosphorus fertilization resulted in a net return of ETB 31,247/ha compared with ETB 21,233/ha obtained with no phosphorus.

Keywords: Faba bean genotypes, plant densities, phosphorus nutrition, yield, nutrient removal, soil fertility changes, economics, vertisols.

INTRODUCTION

Faba bean *(Vicia faba L.)* is one of the major pulse crops grown in the highlands (1800 – 3000 masl) of Ethiopia. The main faba bean global producers are China (1.65 Mt), Ethiopia (0.61 Mt), France (0.44 Mt), Egypt (0.29 Mt) and Australia (0.19 Mt) (FAOSTAT, 2009). The crop takes the largest share of the area under pulses production in Ethiopia. The Central Statistical Agency (CSA, 2013/14) reported that faba bean is planted to 4.34 % (about 538,458.21ha), of the grain crop area with an annual production of about 9,917,002.83 quintals, 3.94 % of the total grain production and yield of 18.42 Qt/ha in Ethiopia. It is grown in several regions of the country with an annual rain fall of 700 – 1000 mm. It is a crop of manifold merits in the economy of the farming communities in the highlands of Ethiopia and serves as a source of food and feed and a valuable and cheap source of protein, apart from playing a significant role in soil fertility restoration in crop rotation through fixation of atmospheric nitrogen. It is mainly produced in Tigray, Gondar, Gojjam, Wollo, Wollega, Shoa and Gamo-Gofa regions of the nation. The export of Ethiopia's faba beans has moved upward since the year 2000 and the major destinations are Sudan, South Africa, Djibouti, Yemen, Russia and USA, though its share in the countries pulse export is small (Amanuel *et al.*, 1993, Newton *et al.,* 2011). Despite the importance, the productivity of the crop is far below the potential and is constrained by several limiting factors.

In Ethiopia, Faba bean is raised by farmers at varied row spacing resulting in dwindled productivity. Plant density is an important component that ultimately determines the yield of crop per unit area; per unit time. In addition to this, being a legume, it needs phosphorus for better root and nodule development, which is often neglected by farmers. The inherent low-yielding potential of the indigenous cultivars is among the most important production constraints (Asfaw *et al*., 1994; Yohannis, 2000). Moreover, diseases like chocolate spot (*Botrytiss fabae*), rust (*Uromyces vicia fabae*) and root rot (*Fusarium solani*) and abiotic stresses like waterlogging have all been identified as important production constraints (Asfaw *et al*., 1994; Amare ,1990.). Apart this, in vertisols of Ethiopian highlands, phosphorous is fixed and its non-availability is a challenge for better crop growth and development. It is known that Phosphorous nutrition plays a prime role in growth and development of roots and its role in nodulation, dry matter production, N fixation, and protein synthesis of leguminous crops is vital (Haque *et al.; 1986)*, although the crop nutrition for nitrogen is met through rhizobial fixation of atmospheric nitrogen. The need of P for faba bean is high due to energy expenditure in nodule formation (Kopke and Nemecek,2010).Hence a balanced nutrition of legumes gains significance to harvest better yields, specially under rain fed cropping conditions, where rain fall quantum and its distribution controls the total crop production system.

Nitrogen and Phosphorous interact closely in affecting plant maturity. Phosphorous is implicated in speeding up maturity and enhancing root-shoot growth ratio, the formation of glycol-phosphate involved in photosynthesis, respiratory metabolism, apart from being a part of nucleotides (RNA, DNA) and phospholipids of membranes and play a role in energy transfer metabolism (ATP, ADP, AMP, Pyro-phosphates) (Salisbury and Ross, 1992).The high yield potential of faba bean has not been exploited in Ethiopia and the yield in the southwestern Ethiopian highlands is generally low (1.3 ton ha^{-1}. compared to 1.8 ton ha^{-1} world average) (FAOSTAT, 2008). This is largely attributed to raising low yielding local varieties, low soil pH and low P-availability in Nitisols (Agegnehu *et al.*, 2006, Agegnehu and Chilot, 2009). However, faba bean has the capacity to mobilize soil phosphorus by secretion of acids from its rhizosphere, and is therefore of important value in low-input crop rotation systems (Nuruzzaman *et al*., 2005). The yield potential and N fixation has been reported to be high in deep, heavy clay soils (Kopke and N emecek,2010).Besides, there is dearth of information on the optimum plant density to reap better harvests. Therefore, the present investigation was made to evaluate the performance of faba bean genotypes in relation to varied plant densities and phosphorus levels, to know the uptake of N P nutrients, soil fertility changes and economic analysis of these production factors under rain-fed vertisol conditions of central highlands of Ethiopia.

MATERIALS AND METHODS

Description of the study area

The field experiment was conducted under rain-fed condition at Ambo University research farm during the main cropping season of 2014 on vertisol. Ambo is located in the West Shoa Zone of Oromia Regional State, Western Ethiopia, at about 115 km west of Addis Ababa, located within Coordinates: 8°59′N 37°50′E , and an altitude of 2068 m.a.s.l. The seasonal total rain fall of the area during the crop season was 570 mm, with the average minimum and maximum temperature of 9.2 ^{0}C and 27.08 ^{0}C, mean relative humidity of 58.02 % and a mean sun shine hours of 5.62 day^{-1}, respectively. The soil on which the experiment was conducted is characterized by Pellic vertisol (Tesfaye Balemi, 2012). The farm area preceding the current faba bean was a fallow.

Experimental materials

In the current experiment two improved high yielding genotypes of faba bean viz; Hachalu and Walki, which are adapted to the vertisols of the highland areas were compared with a local cultivar. The varieties Hachalu and Walki are recommended for highlands vertisols of Ethiopia (Ambo, Adadi, Arsi, Robe, Sinja and etc.) with altitudes of 1900-2800 m.a.s.l, having a rain fall of 700-1000 mm for planting in mid-June to early July, moderately resistant to chocolate spot and rust, released from HARC /EIAR in 2010 and 2008, respectively. The days to maturity of Hachalu and Walki are 122 – 156 & 133 – 146, respectively. The potential yields of Hachalu & Walki variety were 32- 45 & 24-52 quintal ha^{-1} on research stations and 24–35 & 20-42 quintal ha^{-1} on farmer's field, respectively (EIAR, 2011).

Treatments and design

The treatments consisted of three faba bean genotypes (Hachalu, Walki and a local cultivar) tested as main -plot treatments; three spacing's (30 x 7.5 cm, 40 x 5 cm and 60 x 5 cm) as sub - plot treatments and two phosphorous levels (0 and 46 kg P_20_5 ha^{-1}) assigned as the sub-sub plot treatments, all combined factorial in split-split plot design with three replications.

Analysis of soil and plant

The initial soil samples were collected from randomly selected sites of the experimental plots from a depth of 0- 30 cm prior to cultivation and fertilizer application. The composite soil samples were analyzed for physical and chemical properties, using standard procedures with reference to pH, CEC, organic carbon, total N, available P and K to evaluate the initial nutrient status. After the crop harvest, the soil of each treatment was analyzed for N, P, and K status. The soil physicochemical and plant tissue analysis was carried out at Holetta Agricultural Research Center (HARC), Soil and Plant Tissue Analysis Laboratory. The soil samples were air dried and ground to pass through 0.2 mm sieves for total N. All samples were analyzed following standard procedures. Organic carbon was determined by wet digestion method as described by Walkley and Black (1934).Total N was estimated by Kjeldahl method described by Jackson (1958). Available P in soil was determined by Olsen method (Olsen *et.al.*, 1954). Soil texture was analyzed by Bouyoucos hydrometer method (1955) and Soil pH was measured by glass electrode pH meter. The plant samples were analyzed (seed, haulm) for N and P contents to calculate the nutrient uptake treatment wise. Protein content of seed was calculated based on N content of seed.

Field operations

The field was cleared, plowed thoroughly twice by a tractor and harrowed twice to obtain a fine tilth free from weeds. The field was then marked out into 18 plots per replication each of 3 m^2 (1 m x 3 m). Planting was done on 7 July 2014. Two seeds of each genotype were planted per hill at a depth of 2 –3 cm using three spacing's (30 x 7.5 cm, 40 x 5 cm and 60 x 5 cm) to obtain 444,444, 500,000 and 333,333 plants ha^{-1}, respectively. Thinning was carried out two weeks after germination to maintain one plant/hill. The source of phosphorus was Di-ammonium phosphate which was applied pre- planting at the rate of 0 kg P_20_5 and 46 kg P_2O_5 ha^{-1}. Nitrogen was applied uniformly at 18 kg N ha^{-1} as a starter dose with urea and DAP being the sources of N. DAP was applied at the time of sowing.In the current experiment chocolate spot and rust diseases were observed which were managed using a fungicide Mancozeb 80 WP (Dithane M-45), at the rate of 2.5 kg a.i/ha at weekly intervals 3 times as foliar spray. Harvest of the crop was carried out at physiological maturity on 19 November 2014, and further subjected to sun drying to standardize the seed moisture content to 10 percent. Net plots were harvested leaving border rows to determine the per plot yields of beans and haulms.

Observations recorded on crop

The following observations and data were collected on growth, yield and yield components from five randomly selected and tagged representative plants from each net plot.

Nutrient removal

The total uptake of nitrogen and phosphorous was calculated for each treatment employing the formula Nutrient uptake = nutrient concentration (mg $g.dm^{-1}$) x dry biomass weight (mg $plant^{-1}$).

Economic analysis of production factors

Economic analysis (CIMMYT, 1988) of data in relation to different factors of production under test viz; genotypes, plant density and Phosphorus nutrition, was computed in terms of 1. Gross return (ETB ha^{-1}), 2. Net return (ETB ha^{-1}), 3.Cost of Production (ETB ha^{-1}), 4. Benefit**:** Cost ratio (Gross return/Cost of production), 5. Per day Productivity (kg ha^{-1}) (Grain Yield/Crop duration), 6.Return/Birr Investment (Net return/Production cost).

Statistical analysis of data

All the data collected were subjected to the analysis of variance using SAS version 9.1.3 (2009), with Model: $Y_{ijkl} = \mu + r_i + A_j + e_{ij}(a) + B_k + (AB)_{jk} + e_{ijk}(b) + C_l + (CA)_{lj} + (CB)_{lk} + (CAB)_{jkl} + e_{ijkl}$ (c).Where, μ = Population mean, r = replication, A = Main plot, ea = Main plot error, B = Sub plot, eb = Sub plot error, (AB, CA, CB, CAB) = Interaction, C = Sub-sub plot, ec = Sub-sub plot error. Wherever, the treatment showed a significant effect, the Duncan's multiple range test (DMRT) was used for means separation. The treatments were compared for their significance using calculated least significant difference (LSD) values at p = 0.05.

RESULTS AND DISCUSSION

Pre- sowing initial physico-chemical properties of the experimental soil

The pre- planting soil analysis showed that the texture of the soil of the experimental site is dominated by the clay fraction. On the basis of particle size distribution, the soil contains Sand 2.5 %, Silt 22.5 %, and Clay 75 % (Table 1). The soil reaction (pH) of the experimental site is 6.79, which was near neutral. According to FAO (2008), suitable pH range for most crops is between 6.5 and 7.5 in which total N availability is optimum. This indicates suitability of the soil reaction in the experimental site for optimum crop growth and yield (Table 1). The organic carbon content of the soil was 1.17%. According to Tekalign (1991) the soil has low organic carbon content, indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic carbon. Analysis of soil samples from 0-30 cm depth indicated low (0.070%) level of total N, indicating that the nutrient was not optimum for crop growth, and the available phosphorus content of the soil, is low (5.94 ppm). The K content of soil was 1.63 meq/100g; while the Cation exchange capacity was 1.17 meq/100 g soils.

Crop growth in relation to weather

The meteorological parameters that have profound influence on crop growth in terms of seasonal rain fall, minimum temperature, maximum temperature, relative humidity% and sunshine hours/day are presented in Figure 1. In the present study, faba bean was sown on 7, July 2014 and harvested on 19, November 2014. The maturity period of faba bean ranges from 90 – 220 days depending up on cultivars and climate (Bond *et al.,* 1985). The crop received a seasonal rain fall of 570 mm from June to November with uniform distribution from June through August and tapering towards September through November.

Table 1. Selected physico-chemical properties of the experimental soil before sowing

Physical properties				Chemical properties					
Particle size distribution (%)									
Sand	Silt	Clay	Textural class	pH	OC (%)	CEC (Meq/100g)	Total N (%)	Av. P (ppm)	K (Meq/100g)
2.5	22.5	75	Clay	6.79	1.17	1.17	0.07	5.94	1.63

Table 2: Interaction effect of genotype with P level on pod length (cm) of faba bean.

Genotype	Phosphorus level 0 P_2O_5 kg/ha	Phosphorus level 46 P_2O_5 kg/ha	Mean
Hachalu	6.14	6.24	6.19
Welki	5.59	6.49	6.04
Local	4.56	4.61	4.58
Mean	5.43	5.78	
LSD (0.05)	0.29		

Table5 : Interaction effect of genotype x plant density x phosphorus levels on pod length of faba bean.

Genotype	Pod Length (cm)						
	0 kg P_2O_5/ha			46 kg P_2O_5/ha			
	44 plants/m^2	50 plants/m^2	33 plants/m^2	44 plants/m^2	50 plants/m^2	33 plants/m^2	Mean
Hachalu	6.60	5.67	6.17	5.77	6.33	6.63	6.19
Welki	5.50	5.73	5.53	6.83	6.53	6.10	6.04
Local	4.47	4.40	4.80	4.47	4.43	4.93	4.58
Mean	5.52	5.27	5.50	5.69	5.77	5.89	
LSD (0.05)	0.69						

Kay (1979) reported that the annual rain fall of 650 – 1000 mm evenly distributed is ideal for faba bean. The crop thus had ample opportunity of experiencing adequate moisture supply favorable for better vegetative growth and development. The minimum temperature varied between 6.8 ^{0}C to 11.3 ^{0}C, the maximum being in July and in the minimum in November when the crop is in anthesis and floral development. The maximum temperature oscillated between 25.5 ^{0}C and 29.6^{0}C with maximum in June, lowered in July and August, and gradually escalated from September through November when the crop is in transition from vegetative to reproductive stage. Duke (1981), reported that the optimum temperature for faba bean production range from 18 to 27^{0}C (65 – 85^{0}F).The crop experienced a relative humidity ranging from 44% to 69.9%, peaking in August and tapering towards November gradually. The mean sun shine hours/day hovered between 3.1 and 8.8 in July and November, respectively providing ample opportunity for photosynthetic assimilation of CO_2 even through the reproductive period.

Yield and yield components of faba bean Pods plant^{-1}

The local cultivar produced more number of pods (21.6) compared to the improved genotypes that produced 19.2 and 18.6 pods/plant in Hachalu and Walki, respectively. With regard to plant densities, the number of pods/plant did not differ significantly, though 30 x 7.5 cm spacing tended to produce more pods/plant. Faba bean did not respond to phosphorus application in terms of pod number/plant. The pods number/plant is a genetic character and is less influenced by the environment in terms of plant density and P nutrition (Table 6). These results are in agreement with Gemechu *et al.,* (2006) who reported 3 to 15 pods/plant for faba bean genotypes in different geographical regions of Ethiopia. Davood Hashemabadi (2013) also observed increase in plant height, fresh weight, and pod number with 80 kgP_2O_5/ha.

Pod Pod weight/plant (g)

The genotype Hachalu produced highest pod weight/plant (24.3 g) followed by Walki (23.5 g) and the local cultivar (20.9 g) (Table 6). Wider spacing of 60 x 5.0 cm resulted in substantially greater pod weight/plant (24.3 g) than 30 x 7.5 cm (22.9 g) and 40 x 5.0 cm spacing (21.5 g). This indicates that pod weight/plant can be altered by plant spacing. The greater pod weight/plant recorded with low plant density could be attributed to less competition for growth resources like soil moisture, nutrients and sun light as compared to the dense stands. Faba bean exhibited significant response in terms of greater pod weight/plant with application of 46 kg P_2O_5/ha (24.0 g) compared to 21.7 g obtained with no phosphorus. This signifies the beneficial role of phosphorus in improving the pod weight of faba bean .

Seeds pod^{-1}:

Seeds/pod did not vary significantly among the genotypes, while it tended to vary with plant density and phosphorus nutrition (Table 6).

By and large, the seed number/pod of the test genotypes remained at 3. Among the spacings, wider spacing tended to improve the seeds/pod (3.0) as compared with narrow spacings (2.7). On the other hand, phosphorus application tended to improve seeds/pod (3.0) when compared with no phosphorus (2.8). The number of seeds/pod varied distinctly when Hachalu fertilized with 46 kgP_20_5/ha and sown at wider spacing of 60 x 5.0 cm (3.33) than when, sown at 30 x 7.5 cm (2.33) as evident from interaction (Table 7). Interaction effect of genotype, plant density and phosphorus levels on seeds pod^{-1} of faba bean (Table 8) showed that local cultivar was relatively superior (2.94) to Hachalu (2.89) and Welki (2.83). With the application of phosphorus fertilizer and sowing at a spacing of 60 x5.0 cm Hachalu produced more seeds/pod (3.33) than Walki (3) and local cutivar. In general, as the seeds/pod is a genetic character, it is less influenced by either management or P nutrition. These results are in agreement with Gemechu *et al.,* (2006) who reported that seeds pod^{-1} of faba bean genotypes ranged from 2-3.

Number of seeds plant^{-1}

Among the test genotypes, the local cultivar produced significantly more number of seeds/plant (36.6) than the improved genotypes, Hachalu (30.7) and Walki (35.1)(Table 6). This could be due to production of more number of pods/plant in the former and its better adaptation to the environment even under moisture stress conditions than in the latter genotypes. With regards to planting density, low density planting adopting wider spacing (60 x5.0 cm) offered significantly more number of seeds/plant (37.3) in comparision with high density planting with 30 x 7.5 cm (33.1) and 40 x 5.0 cm (32) under rain fed conditions.The crop fertilized with 46 kg P_20_5/ha produced significantly more number of seeds/plant (35.2) than the unfertilized crop (33.1), high lighting the importance of phosphorus nutrition in faba bean. Interaction between genotypes and phosphorus levels showed that the local genotype produced significantly more seeds/plant (39.1) when compared to that produced by Welki (36.1) and Hachalu (30.4) (Table 8).

Seed weight plant^{-1}(g)

Among the genotypes, Hachalu produced maximum seed weight/plant (18.7 g) followed closely by Walki (17.8 g) and the least weight by the local cultivar (16.24 g)(Table 6). This reveals that the partitioning efficiency is better in improved faba bean genotypes than the local traditional cultivar; which is of para amount importance in enhancing seed yields per unit area. The seed weight/plant showed distinct variation in relation to different plant densities. Sparse density (60 x 5.0 cm) resulted in significantly higher seed weight/plant (18.24 g) than dense plant stands of 30 x 7.5 cm (18.0 g) and 40 x5.0 cm (16.52 g). The reduction in seed weight/plant in dense stands could be due to greater inter- plant competition for growth resources like soil moisture, nutrients and sun light. Crop fertilization with 46 kg P_20_5/ha brought about substantial improvement in seed weight/plant (18.42 g) in comparison with un fertilized crop (16.75 g) indicating the role of phosphorus in improving seed weight of faba bean.

Test weight of seed (g)

Among the genotypes, Hachalu recorded substantially greater test seed weight (650 g) compared to Walki (524 g) and the local cultivar which recorded the least weight (344 g)(Table 6). This elucidates the greater assimilatory efficiency of the improved genotypes than that of traditional cultivars. High density of 44 plants/m^2 (508 g) and 50 plants/m^2 (517 g) had seeds of greater weight than low density planting at 33 plants/m^2 (492 g).Phosphorus fertilization at 46 kg P_20_5/ha significantly improved the test seed weight (520 g) over no phosphorus (492 g). These results are in agreement with Gemechu *et al.,* (2006) who found that 1000 seed weight of faba bean genotypes ranged from 249-553 g.

Table 6: Effect of genotypes, plant density and P fertilizer levels on yield and yield components of Faba bean.

Treatments	Yield and yield components of faba bean											
	Pods/plant	Pod Length (cm)	Pod Weight/Plant (g)	No. of Seeds/pod	No. of Seeds/plant	Seed weight/Plant (g)	Seed Yield/plot (g)	1000 Seed wt. (g)	Biological Yield/plot (g)	Seed Yield (kg/ha)	Biological Yield (kg/ha)	Harvest Index (%)
Genotype												
Hachalu	19.17b	6.19a	24.27a	2.89a	30.72b	18.72a	911.11ab	650.06a	1908.4a	3037.0ab	6361.4a	48.17a
Welki	18.61b	6.04a	23.47a	2.83a	35.11a	17.80ab	1022.22a	523.89b	2092.1a	3407.4a	6973.5a	48.42a
Local	21.56a	4.58b	20.90a	2.94a	36.61a	16.24b	850.00b	344.06c	1747.7a	2833.3b	5825.7a	49.10a
Mean	**19.78**	**5.61**	**22.88**	**2.89**	**34.15**	**17.59**	**927.78**	**506**	**1916.07**	**3092.6**	**6386.9**	**48.57**
LSD (0.05 %)	**2.16**	**0.99**	**NS**	**NS**	**6.06**	**2.36**	**169.32**	**34.7**	**NS**	**564.4**	**NS**	**NS**
CV%	**11.79**	**19.19**	**17.25**	**15.08**	**19.18**	**14.52**	**19.72**	**7.41**	**19.92**	**19.72**	**19.92**	**4.58**
Pl. density/m²												
44	20.00a	5.61a	22.87ab	2.72b	33.11b	18.00a	1144.44a	508.89a	2368.25a	3814.8a	7894.2a	48.93a
50	19.50a	5.52a	21.46b	2.94a	32.00b	16.52b	922.22b	517.33a	1971.05b	3074.1b	6570.2b	47.32a
33	19.83a	5.69a	24.31a	3.00a	37.33a	18.24a	716.67c	491.78b	1408.89c	2388.9c	4696.3c	49.45a
Mean	**19.78**	**5.61**	**22.88**	**2.89**	**34.15**	**17.59**	**927.78**	**506**	**1916.07**	**3092.6**	**6386.9**	**48.57**
LSD (0.05 %)	**NS**	**NS**	**1.75**	**0.22**	**2.14**	**1.35**	**50.39**	**16.93**	**110.19**	**167.98**	**367.29**	**NS**
CV%	**10.53**	**8.17**	**10.55**	**10.38**	**8.66**	**10.57**	**7.48**	**4.6**	**7.91**	**7.48**	**7.91**	**9.9**
P_2O_5 (kg/ha)												
0	19.33a	5.43b	21.75b	2.81a	33.07b	16.75b	796.36b	492.16b	1680.51b	2654.3b	5601.7b	47.45a
46	20.22a	5.78a	24.01a	2.96a	35.22a	18.42a	1059.26a	519.82a	2151.62a	3530.9a	7172.1a	49.69a
Mean	**19.78**	**5.61**	**22.88**	**2.89**	**34.15**	**17.59**	**927.78**	**506**	**1916.07**	**3092.6**	**6386.9**	**48.57**
LSD (0.05 %)	**NS**	**0.23**	**2.4**	**0.19**	**1.75**	**1.84**	**75.34**	**17.5**	**139.5**	**251.14**	**465.01**	**NS**
CV%	**11.45**	**7.35**	**18.35**	**11.54**	**8.95**	**18.3**	**14.2**	**6.05**	**12.73**	**14.2**	**12.73**	**11.64**
Interaction												
G x Pl									*	*	*	
G x P		*			*		*			*		
Pl x P												
G x Pl x P		*		*								

Means in same columns followed by the same letter(s) are not significantly different, *. = significant.

Table 7: Interaction effect of genotypes, plant density and phosphorus levels on Seed pod^{-1}of faba bean.

Genotype	0 kg P_2O_5			46 kg P_2O_5			
	44 plants/m^2	50 plants/m^2	33 plants/m^2	44 plants/m^2	50 plants/m^2	33 plants/m^2	Mean
Hachalu	3.00	2.67	3.00	2.33	3.00	3.33	2.89
Walki	2.33	3.00	2.67	3.00	3.00	3.00	2.83
Local	2.67	3.00	3.00	3.00	3.00	3.00	2.94
Mean	2.67	2.89	2.89	2.78	3.00	3.11	
LSD (0.05)	0.41						

Table 8: Interaction effect of genotype with phosphorus levels on number of seeds plant^{-1}of faba bean.

Genotype	Phosphorus level		Mean
	0 kg P_2O_5	46 kg P_2O_5	
Hachalu	31.00	30.40	30.70
Welki	34.10	36.10	35.10
Local	34.10	39.10	36.60
mean	33.07	35.20	
LSD (0.05)	3.15		

Table 9: Interaction effect of genotype with plant density on biological yield of faba bean.

	Biological Yield (kg/ha)			
Genotype	44 plants/m^2	50 plants/m^2	33 plants/m^2	Mean
Hachalu	7915.77	6465.6	4702.74	6361.37
Welki	8367	7630.58	4923.01	6973.53
Local	7399.74	5614.34	4463.11	5825.73
Mean	7894.17	6570.17	4696.29	
LSD (0.05)	400.85			

Biological yield (kg ha^{-1})

The biological yield followed a trend similar to that of seed yield/plot. Improved genotypes of Walki (6973.5 kg/ha) remaining at par with Hachalu (6361.4 kg/ha) produced significantly higher biological yield/plot than that of local variety (5825.7 kg/ha). This shows that improved cultivars have the potential to produce more dry matter than the local genotype. Higher plant densities represented by closer spacing of 30 x 7.5 cm (7894.2 kg/ha) and 40 x 5.0 cm (6570.2 kg/ha) produced superior biological yield kg/ha to that of wider spacing 60 x 5.0 cm (4696.3 kg/ha). Significantly greater biological yield kg/ha has been obtained with the application of 46 kgP_2O_5/ha (7172.1 kg/ha) than that obtained in no phosphorus plots (5601.7 kg/ha). Significant interaction between genotype and spacing on biological yield/ha showed that irrespective of genotype there was reduction in biological yield/ha with reduced plant density. The genotype Walki grown with a spacing of 30 x 7.5 cm produced significantly higher biological yield 8,367 kg/ha than the other genotype spacing combinations. The next best is Hachalu raised with 30 x 7.5 cm spacing of produced 7,915.77 kg/ha and the local cultivar produced 7399.74 kg/ha (Table 9).

Seed yield (kg ha-1)

Among the faba bean genotypes, Walki (3407 kg/ha) and Hachalu (3037 kg/ha) gave significantly higher productivity than the local genotype (2833 kg/ha)(Table 6). The percentage yield enhancement of Walki and Hachalu over local chek was 20 and 7.2 %, respectively. The superior performance of Walki could be attributed to more length of pods, greater pod weight/plant, higher seed weight/plant, more seeds/plant, higher test seed weight, ultimately leading to substantial enhancement in seed yield/plot. Bianchi *l.,* (1979) also reported that the number of seeds/pod and seed weight are most stable components and seed weight varies between cultivars and range from 0.1g to 2.4g/seed. Among the plant densities, seeding at 30 x 7.5 cm (44 plants/m^2) resulted in superior seed productivity (3814.8 kg/ha) than that obtained with 40 x 5.0 cm (50 plants/m^2) (3074.1 kg/ha) and 60 x 5.0 cm (33 plants/m^2) (2388.9 kg/ha). Significant interaction effect between genotype x plant density on seed yield revealed that by and large, all the genotypes yielded maximum with 30 x 7.5 cm spacing, closely followed by 40 x 5.0 cm spacing, while their yields significantly dwindled with wider spacing of 60 x 5.0 cm. The genotype Walki seeded at a spacing of 30 x 7.5 cm surpassed (4166.7 kg/ha) the rest of the genotype x spacing combinations in seed productivity (Table 10). The next best was Hachalu grown at 30 x 7.5 cm (3777.8 kg/ha) in terms of productivity. Fertilizing the crop with 46 kg P_20_5/ha resulted in significantly greater seed yield (3531 kg/ha) than that without P fertilizer (2654 kg/ha) in vertisols. Application of 80 kgP_20_5/ha has been reported to give 13 t/ha green pods of faba bean (Davood and Hashemabadi, 2013; Salih, 1986, Balaban and Sepetoglu, 1991; Babiker, 1995). Hamissa (1973), based on results of 31 fertilizer trials (1967-1973) on faba bean concluded that response to phosphorus was high, increasing P from 36 to 72 kg/ha increased yield by 9.8 and 15.7% over control. There was significant interaction between genotype x phosphorus on seed yield, where Walki fertilized with 46 kg P_20_5/ha gave greater productivity (4074 kg/ha) than the rest of the combinations. The next best was Hachalu grown with 46 kg P_20_5/ha (3407 kg/ha).

Table 10. Interaction effect of genotype and plant density on seed yield (kg/ha) of faba bean.

Genotype	Population density			Mean
	44 plants/m^2	50 plants/m^2	33 plants/m^2	
Hachalu	3777.78	2944.44	2388.89	3037.04ab
Walki	4166.67	3555.56	2500	3407.41a
Local	3500	2722.22	2277.78	2833.33b
Mean	3814.81a	3074.07b	2388.89c	
LSD (0.05)		205.76		

Table 11. Interaction effect of genotype with phosphorus on seed yield (kg/ha) of faba bean.

Genotype	Phosphorus level		
	0 P_20_5 kg/ha	46 P_20_5 kg/ha	Mean
Hachalu	2666.67	3407.41	3037
Walki	2740.74	4074.08	3407.4
Local	2555.55	3111.11	2833.33
Mean	2654.3	3530.9	
LSD (0.05)	198.4		

Thus the new genotypes responded better to phosphorus application than the local cultivar (3111 kg/ha) (Table 11). Seed yield of faba bean is a product of number of plants/m^2, number of pod bearing nodes/plant, pods/node, seeds/pod and seed weight (Thompson and Taylor, 1977; Ishag, 1973).

Harvest Index (HI)

The genotypes did not differ in harvest index. Low density planting 60 x 5.0 cm (33 plants/m^2) resulted in higher harvest index (49.45) over high density seeding at 30 x 7.5 cm (44 plants/m^2) (48.93) and 40 x 5.0 cm (50 plants/m^2) (47.32) which gave comparable harvest index. Harvest index was not much altered among the genotypes; though the seed yields exhibited distinct variation; which was due to non-significant variation in biological yield per unit area. The application of phosphorus tended to improve the harvest index (49.69) of faba bean when compared with no P application (47.45) through the variation was not discernible. Application of 50 kgP_20_5 has been reported to enhance nodulation and yield of faba bean in soils having 3.5 and 2.0 ppm P at ICARDA (Murinda and Saxena, 1983).

Correlation between Seed yield, growth and yield components

Correlations between growth, yield and yield components showed a significant positive relation between seed yield and plant height at different stages, leaf area/plant, leaf area index, biological yield and seed yield/plant. Biomass yield was correlated with leaf area/plant, LAI and plant height .

Nitrogen and phosphorus removal of faba bean

The results showed that the uptake of nutrients differed between genotypes and also with spacing (Table 12). In the uptake of phosphorus (mg plant^{-1}) the improved genotypes Hachalu (909.27 mg/plant) and Walki (966.29 m/plant) surpassed the uptake by local cultivar (838.72 mg/plant) with 30 x 7.5 cm spacing. Walki genotype proved better than other in total N (mg plant^{-1}), when raised with 30 x 7.5 cm spacing closely followed by Hachalu at the same plant density. The local genotype removed relatively less NP nutrients than Walki and Hachalu in the respective spacing. In general, nutrient up-take mainly depends on ability of genotype to extract nutrients and spacing also affected the up-take of nutrient. As faba bean is having naturally biological nitrogen fixing ability, the study showed that the up-take of nitrogen by plant remained greater when sown in dense stands than in sparse stands in all the test genotypes.

Nitrogen removal (kg/ha) in seed

The N content in grain (3.15 %) has been greater than that of stalks (0.82 %). The P content of grain (0.32 ppm) was higher than that in stalks (0.05 ppm). As the nutrient removal is the product of nutrient content in plant tissue and biomass yield, the nutrient removal followed the trend of seed yield and biomass yield in relation to different production factors under investigation (Table 13). The nitrogen removal in seed of different genotypes varied where improved genotype Walki removed maximum (107.33 kg/ha) closely followed by Hachalu (95.67 kg/ha), while the least was removed by local cultivar (89.25 kg/ha).The influence of plant density on N removal by seed showed that higher plant density (44 plants/m^2) removed maximum (120.17 kg/ha) followed by 50 plants/m^2 (96.83 kg/ha) which surpassed low density (33 plants/m^2) (75.25 kg/ha). The N removal is in tandem with the seed yields obtained in different plant densities. Application of 46 kg P_20_5/ha resulted in distinct enhancement in N removal in seed (111.22 kg/ha) over no P application (83.61 kg/ha), suggesting the complementary role played by P in the N removal by the faba bean seed (Table 13). Fageria (2002) also reported beneficiary effect of fertilizer on nutrient uptake, and the removal ranged between 280 – 328 kg/ha for N; 27.7 34 kg/ha for P and 188 – 222 kg/ha for K.

Table 12: Nutrient removal of faba bean genotypes in relation to plant density.

Genotype	Plant density	TN (mg $plant^{-1}$)	P (mg $plant^{-1}$)
Hachalu	44 plants/m^2	14912.1	909.27
	50 plants/m^2	10603.58	646.56
	33 plants/m^2	10885.43	663.75
Walki	44 plants/m^2	15847.13	966.29
	50 plants/m^2	12514.15	763.06
	33 plants/m^2	11973.95	730.12
Local	44 plants/m^2	13755.04	838.72
	50 plants/m^2	9207.52	561.43
	33 plants/m^2	10705.93	652.80

Table 13: Uptake of Nitrogen (kg/ha) in seed of faba bean.

Genotype	Population density			Mean	Population density	P level		Mean
	44 plants/m^2	50 plants/ m^2	33 plants/m^2			0 kg P_20_5/ha	46 kg P_20_5/ha	
Hachalu	119	92.75	75.25	95.67	44 pl/m^2	106.16	134.17	120.17
Welki	131.25	112	78.75	107.33	50 pl/m^2	82.83	110.83	96.83
Local	110.25	85.75	71.75	89.25	33 pl/m^2	61.83	88.66	75.25
Mean	120.17	96.83	75.25	97.41		83.61	111.22	97.41

Table 14: Protein yield (kg/ha) of genotypes, plant densities and P nutrition of faba bean.

Genotype	0 kg P_20_5/ha				46 kg P_20_5/ha			
	44 plants/m^2	50 plants/m^2	33 plants/m^2	Mean	44 plants/m^2	50 plants/m^2	33 plants/m^2	mean
Hachalu	678.56	503.44	394.00	525.33	809.89	656.67	547.22	671.26
Walki	656.67	591.00	372.11	539.93	985.00	809.89	612.89	802.59
Local	656.67	459.67	394.00	503.44	722.33	612.89	503.44	612.89
mean	663.96	518.04	386.70	522.90	839.07	693.15	554.52	695.58

Protein yield of faba bean

Depending upon the N content of seed the protein content was calculated as: Protein % = N % x 6.25. The protein content varied in relation to genotypes, apart from agronomic practices such as plant density and P fertilizer application. Results in Table 14 showed that improved genotypes with different P levels responded better than the local cultivar in protein content and protein yield, especially Walki genotype performed better than others. Regarding plant density, 44 plants/m^2 recorded higher protein yield than 50 plants /m^2 and 33 plants /m^2. Chavan *et al.* (1989) reported a wide variation in protein content of faba bean (20 – 41%), and winter beans have higher protein content than spring faba beans (Bond *et al.,* 1985). Protein content is influenced by both genetic and environmental factors. Winter and spring types of faba bean showed different compositions of not only protein but also among different amino acid varieties (Ford and Hewitt, 1980).

Phosphorus removal (kg/ha) in seed

The P content of grain (0.32 ppm) was higher than that in stalks (0.05 ppm). The phosphorus removal in seed of different genotypes varied where improved genotype Walki removed the maximum amount (10.9 kg/ha) closely followed by Hachalu (9.72 kg/ha), while the least was removed by the local cultivar (9.07 kg/ha).The influence of plant density on P removal by seed showed that higher plant density (44 plants/m^2) removed the maximum amount (12.21 kg/ha) followed by 50 plants/m^2 (9.84 kg/ha) which surpassed low density (33 plants/m^2) (7.64 kg/ha). The P removal is in tandem with the seed yields obtained in different plant densities. Application of 46 kg P_20_5/ha resulted in distinct enhancement in P removal in seed (11.29 kg/ha) over no P application (8.49 kg/ha) (Table 15). Hill-cottingham and Sarisum (1980) also reported that the fruits of faba bean made dominant contribution for N, P, K, S to the whole plant total. The stems and leaves contained most P, K in mid-July, most N in end July, while Ca, Mg accumulation continued till mid-August, and the greater part of NPKS in harvested bean has been absorbed directly from soil. In faba bean 80% total seed protein is in cotyledon as non-metabolic reserve (Wallace, 1951).

Nitrogen removal (kg/ha) in haulm

The improved genotype Walki removed the maximum N (57.64 kg/ha) followed by Hachalu (51.86 kg/ha), while the least was removed by local cultivar (47.62 kg/ha).The influence of plant density on N removal by haulm showed that higher plant density (44 plants/m^2) removed the maximum (65.95 kg/ha) followed by 50 plants/m^2 (53.87 kg/ha) which surpassed low density (33 plants/m^2) (37.29 kg/ha). The N removal is in tandem with the haulm yields obtained in different plant densities. Application of 46 kg P_20_5/ha resulted in distinct enhancement in N removal in haulm (59.62 kg/ha) over no P application (45.12 kg/ha), suggesting the complementary role played by P in the N removal by the faba bean haulm (Table 16). Removal of nutrients has been reported to increase significantly with increase in dry matter production, while responses varied with genotypes in faba bean (Ihsanullah Daurl *et al.,* 2010), which is in agreement with the present findings.

Table 15: Uptake of Phosphorus (kg/ha) in seed of faba bean.

Genotype	Population density			Mean	Plant density	P level		Mean
	44 plants/m^2	50 plants/m^2	33 plants/m^2			0 kg P_20_5/ha	46 kg P_20_5/ha	
Hachalu	12.09	9.42	7.64	9.72	44 pl/m^2	10.78	13.63	12.21
Welki	13.33	11.38	8.00	10.90	50 pl/m^2	8.41	11.26	9.84
Local	11.20	8.71	7.29	9.07	33 pl/m^2	6.28	9.00	7.64
Mean	12.21	9.84	7.64	9.89		8.49	11.29	9.89

Table 16: Uptake of nitrogen (kg/ha) in haulm of faba bean.

Genotype	Population density			Mean	Population density	P level		Mean
	44 plants/m^2	50 plants/m^2	33 plants/m^2			0 kg P_20_5 /ha	46 kg P_20_5 /ha	
Hachalu	66.27	53.01	36.28	51.86	44 pl/m^2	58.35	73.55	65.95
Walki	70.43	62.57	39.91	57.64	50 pl/m^2	46.96	60.79	53.87
Local	61.13	46.04	35.68	47.62	33 pl/m^2	30.06	44.53	37.29
Mean	65.95	53.87	37.29	52.37		45.12	59.62	52.37

Table 17: Uptake of phosphorus (kg/ha) in haulm of faba bean

Genotype	Population density			Mean	Population density	P level		Mean
	44 plants/m^2	50 plants/m^2	33 plants/m^2			0 kg P_2O_5/ha	46 kg P_2O_5/ha	
Hachalu	4.04	3.23	2.21	3.16	44 pl/m^2	3.56	4.48	4.02
Welki	4.29	3.81	2.43	3.51	50 pl/m^2	2.86	3.71	3.28
Local	3.73	2.81	2.17	2.90	33 pl/m^2	1.83	2.71	2.27
Mean	4.02	3.28	2.27	3.19		2.75	3.63	3.19

Table 17a: Faba bean nutrient removal in seed, haulm and total removal in relation to genotypes, plant densities and P. nutrition.

Genotype	Spacing	P. level (P_2O_5 kg/ha)	Seed yield (kg/ha)	Removal in Seed (kg/ha)		Biomass (kg/ha)	Removal in Halum (kg/ha)		Total up take (seed+haulm) (kg/ha)	
				Ni	P		N	P	N	P
Hachalu	30x7.5cm	0	3444.45	108.5	11.02	7308.2	59.93	3.65	168.43	14.68
	30x7.5cm	46	4111.11	129.5	13.16	8523.33	72.62	4.43	202.12	17.58
	40x5.0cm	0	2555.55	80.5	8.18	5509.27	45.18	2.75	125.68	10.93
	40x5.0cm	46	3333.33	105	10.67	7421.93	60.86	3.71	165.86	14.38
	60x5.0cm	0	2000	63	6.4	4080.91	28.91	1.76	91.91	8.16
	60x5.0cm	46	2777.78	87.5	8.89	5324.58	43.66	2.66	131.16	11.55
Welki	30x7.5cm	0	3333.33	105	10.67	7198.58	59.03	3.6	164.03	14.27
	30x7.5cm	46	5000	157.5	16	9535.42	81.83	4.99	239.33	20.99
	40x5.0cm	0	3000	94.5	9.6	7061.07	57.9	3.53	152.4	13.13
	40x5.0cm	46	4111.11	129.5	13.16	8200.09	67.24	4.1	196.74	17.26
	60x5.0cm	0	1888.89	59.5	6.04	3742.51	29.78	1.82	89.28	7.86
	60x5.0cm	46	3111.11	98	9.96	6103.51	50.05	3.05	148.05	13.01
Local	30x7.5cm	0	3333.33	105	10.67	6839.82	56.09	3.42	161.09	14.09
	30x7.5cm	46	3666.67	115.5	11.73	7959.67	66.18	4.04	181.68	15.77
	40x5.0cm	0	2333.33	73.5	7.47	4611.53	37.81	2.31	111.31	9.77
	40x5.0cm	46	3111.11	98	9.96	6617.16	54.26	3.31	152.26	13.26
	60x5.0cm	0	2000	63	6.4	4063.27	31.5	1.92	94.5	8.32
	60x5.0cm	46	2555.56	80.5	8.18	4862.96	39.88	2.43	120.38	10.61

Phosphorus removal (kg/ha) in haulm

The phosphorus removal in haulm of different genotypes varied where improved genotype, Walki removed the maximum amount (3.51 kg/ha) followed by Hachalu (3.16 kg/ha), while the least was removed by local cultivar (2.90 kg/ha). Balban and Sepetoglu (1991) reported variability in faba bean genotypes for nutrient uptake and their response. The influence of plant density on P removal by haulm showed that higher plant density (44 plants/m^2) removed maximum (4.02 kg/ha) followed by 50 plants/m^2 (3.28 kg/ha), which surpassed low density (33 plants/m^2) (2.27 kg/ha). Application of 46 kg P_2O_5/ha resulted in distinct enhancement in P removal in haulm (3.63 kg/ha) over no P application (2.75 kg/ha) (Tables 17,17a).

Table 18: Selected Chemical properties of the experimental soil after crop harvest:

Treatment			Nutrient in soil at harvest					
Genotype	Spacing	P level (kg P_2O_5/ha)	TN (%)	Av P (ppm)	K (Meq/100g)	Change over the initial (+/-)		
						N	P	K
Hachalu	30 x7.5 cm	0	0.08	1.75	1.53	0.01	-4.19	-0.10
	30 x7.5 cm	46	0.10	1.86	1.58	0.03	-4.08	-0.05
	40 x5.0 cm	0	0.07	1.74	1.55	0.00	-4.20	-0.08
	40 x5.0 cm	46	0.12	1.85	1.59	0.05	-4.09	-0.04
	60 x5.0 cm	0	0.08	1.80	1.56	0.01	-4.14	-0.07
	60 x5.0 cm	46	0.09	1.84	1.59	0.02	-4.10	-0.04
Walki	30 x7.5 cm	0	0.09	1.71	1.58	0.02	-4.23	-0.05
	30 x7.5 cm	46	0.11	1.91	1.61	0.04	-4.03	-0.02
	40 x5.0 cm	0	0.07	1.72	1.53	0.00	-4.22	-0.10
	40 x5.0 cm	46	0.09	1.89	1.62	0.02	-4.05	-0.01
	60 x5.0 cm	0	0.07	1.77	1.52	0.00	-4.17	-0.11
	60 x5.0 cm	46	0.08	1.87	1.55	0.01	-4.07	-0.08
Local	30 x7.5 cm	0	0.07	1.68	1.53	0.00	-4.26	-0.10
	30 x7.5 cm	46	0.09	1.80	1.58	0.02	-4.14	-0.05
	40 x5.0 cm	0	0.07	1.69	1.48	0.00	-4.25	-0.15
	40 x5.0 cm	46	0.09	1.81	1.53	0.02	-4.13	-0.10
	60 x5.0 cm	0	0.07	1.67	1.49	0.00	-4.27	-0.14
	60 x5.0 cm	46	0.09	1.78	1.51	0.02	-4.16	-0.12
Initial status of soil nutrients			0.070	5.94	1.63			

Post-harvest chemical properties of the Soil

The soil chemical properties analysis indicated a change from initial level at post-harvest stage. There has been an increase in % TN, while % P and % K contents decreased due to more uptake by the crop. Genotypes responded differentially based on plant density and Phosphorus levels in nutrient removal from soil (Table 18). There was an increase in total nitrogen content of soil ranging from 0.00 to 0.005% which could be due to the contribution of rhizobial fixation of atmospheric nitrogen in root nodules of faba bean apart from contribution from soil mineralization. However, the available phosphorus content of soil decreased sharply ranging from 4.03 to 4.27 ppm as compared with the initial status; indicating large removal of P by the legume crop. The available potassium content of soil too showed a declining trend as compared with initial status which ranged between 0.15 to 0.01 meq/100g, indicating marginal decline.

Economic analysis of production factors

The results of economic analysis showed that Walki recorded the highest net return (ETB 29,641.92 than Hachalu (24,826.72) while the local variety accrued the least return (ETB 22,178.62). The corresponding benefit**:** cost ratios of Walki, Hachalu and local variety were

Table 19. Economic analysis of faba bean as influenced by genotype, plant density and phosphorus level.

Treatments		Grain yield (kg ha^{-1})	Dry biomass yield of Faba bean (t ha^{-1})	Gross return (Birr ha^{-1})	Cost of Production (Birr ha^{-1})	Net return (Birr ha^{-1})	Benefit : cost ratio (Birr) (GR/PC)	Per day productivity (GY/CD) kg/ha	Return/Birr Investment (NR/PC)
Genotype	Hachalu	3037.0	6.36	39481.00	14654.28	24826.72	2.69	23.36	1.69
	Welki	3407.4	6.97	44296.20	14654.28	29641.92	3.02	26.21	2.02
	Local	2833.3	5.83	36832.90	14654.28	22178.62	2.51	21.79	1.51
Plant density/m^2	44	3814.8	7.89	49592.40	14654.28	34938.12	3.38	29.34	2.38
	50	3074.1	6.57	39963.30	14654.28	25309.02	2.73	23.65	1.73
	33	2388.9	4.69	31055.70	14654.28	16401.42	2.12	18.38	1.12
P. Nutrition (Kg P_20_5/ha)	0	2654.3	5.60	34505.90	13272.50	21233.40	2.60	20.42	1.60
	46	3530.9	7.17	45901.70	14654.28	31247.42	3.13	27.16	2.13

Where, GY= Grain yield, CD= Crop duration, NR= Net return, PC= Production cost, GR= Gross return.

3.02, 2.69 and 2.51, respectively. Maintaining 44 plants/m^2 resulted in higher net return (ETB 34,938.12/ha) than 50 plants/m^2 (ETB 25,309.02/ha) and the lowest with 33 plants/ m^2 (ETB 16,401.42/ha), the benefit: cost ratios being 3.38, 2.73 and 2.12, respectively (Table 19).Application of 46 kg P_20_5/ha resulted in net return of ETB 31,247/ha in comparison with ETB 21,233/ha obtained without P application. The benefit: cost ratios of growing faba bean with and without P were 3.13 and 2.60, respectively. The per day productivity of genotypes varied distinctly where Welki (26.21 kg/ha) surpassed Hachalu (23.36 kg/ha) and local cultivar (21.79 kg/ha) indicating that improved genotypes possess greater production efficiency than traditional types. The net return/Birr investment was 2.02, 1.69 and 1.51 for Walki, Hachalu and local cultivar, respectively. Seeding the crop at 44 plants/ m^2 density offered higher per day productivity (29.34 kg/ha) than that obtained from 50 plants/ m^2 (23.65 kg/ha) and 33 plants/ m^2 (18.38 kg/ha), with the respective net return/Birr investment being 2.38, 1.73 and 1.12. Fertilizing the crop with 46 kg P_20_5/ha resulted in higher per day productivity (27.16 kg/ha) than that with no P application (20.42 kg/ha) and accruing a net return/Birr investment of 2.13 and 1.60, respectively.

CONCLUSIONS

From the foregoing account it could be inferred that the improved genotype Walki (3407 kg/ha) remaining comparable with Hachalu (3037 kg/ha) gave substantially greater seed yield than the local cultivar (2833 kg/ha) .Nutrient (NP) removal of genotypes both in seed and haulm has been greater in Walki and Hachalu than that in local cultivar. The N removal in seed and haulm of Walki was 107 kg/ha and 58 kg/ha, and the corresponding removal of Hachalu being 95 kg/ha and 52 kg/ha; while that of local cultivar was 89 kg/ha and 48 kg/ha, respectively. The P removal in seed and haulm of Walki was 10.9 kg/ha and 3.5 kg/ha, respectively. While the corresponding values for Hachalu were 9.72 kg/ha and 3.16 kg/ha; whereas the removal by the local cultivar was 9.1 kg/ha and 2.9 kg/ha. Nutrient dynamics of soil after harvest of crop showed that there has been an increase in soil N status ranging from 0.00 to 0.05 percent ,and a sharp decline in soil P and K contents after the crop harvest due to greater removal by the crop, which ranged from 4.03 to 4.27 ppm of P and 0.01 to 0.15 meq/100g of K. The NP uptake of faba bean was found to be greater in dense stands(44plants/m2) in comparison with sparse stands regardless of genotype. Phosphorus fertilization at 46 kg P_20_5/ha brought about significant increase in yield components resulting in substantial increase in seed yield (3531 kg/ha) and biological yield (7172 kg/ha) over no fertilizer check (2654 kg/ha seed and 5602 kg/ha haulm yield) besides more harvest index and greater uptake of N and P. Economic analysis of genotypes showed that Walki accrued the highest net returns (ETB 29,642/ha) followed by Hachalu (ETB 24,827/ha) and the local cultivar (ETB 22,178/ha), with the corresponding Benefit: cost ratios of 3.02, 2.69 and 2.51, respectively. Maintaining 44 plants/m^2 resulted in higher net return (ETB 34,938/ha) than 50 plants/m^2 (ETB 25,309/ha) and 33 plants/m^2 (ETB 16,401/ha), with the corresponding Benefit**:** cost ratios of 3.38, 2.73 and 2.12. P application resulted in a net return of ETB 31,247/ha compared with ETB 21,233/ha obtained from no phosphorus treatment, with the respective Benefit**:** cost ratios of 3.13 and 2.60. Application of phosphorus increased the residual N content of soil after crop harvest; while the depletion of soil P and K was more in unfertilized plots.

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